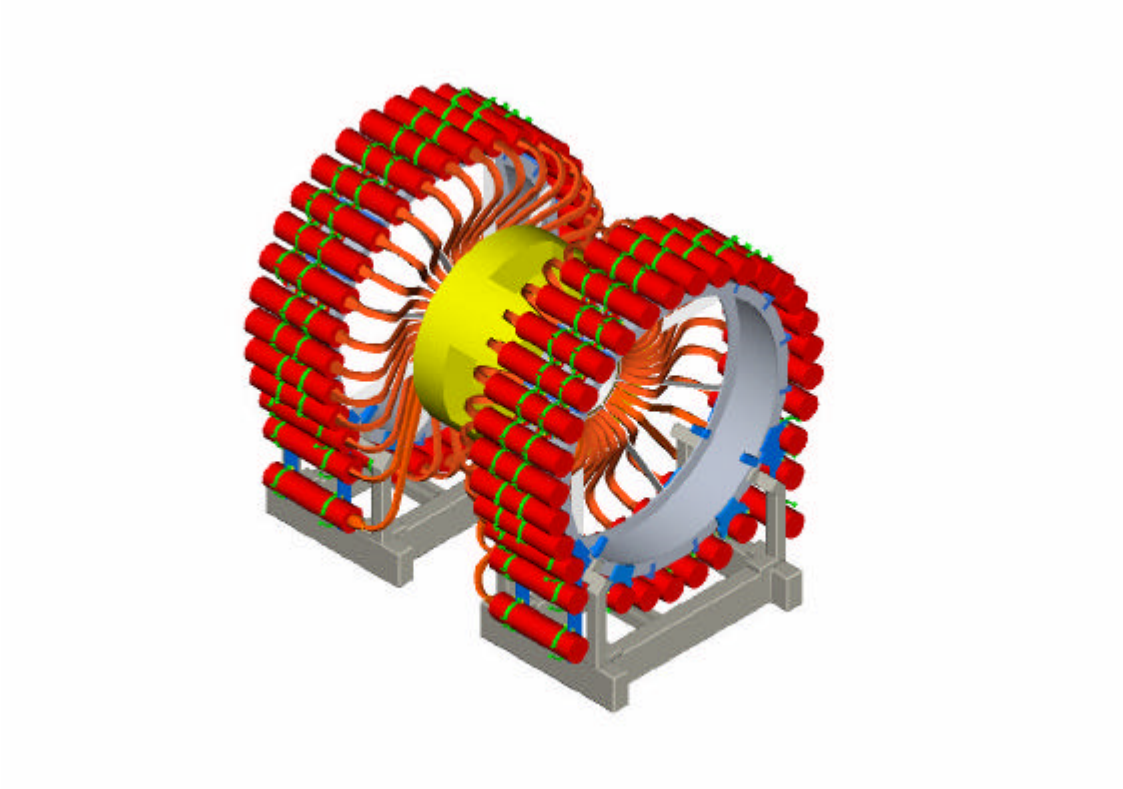
The MuSR User Guide



AD Hillier, PJC King, SP Cottrell, and JS Lord.

ISIS Facility, CCLRC Rutherford Appleton Laboratory

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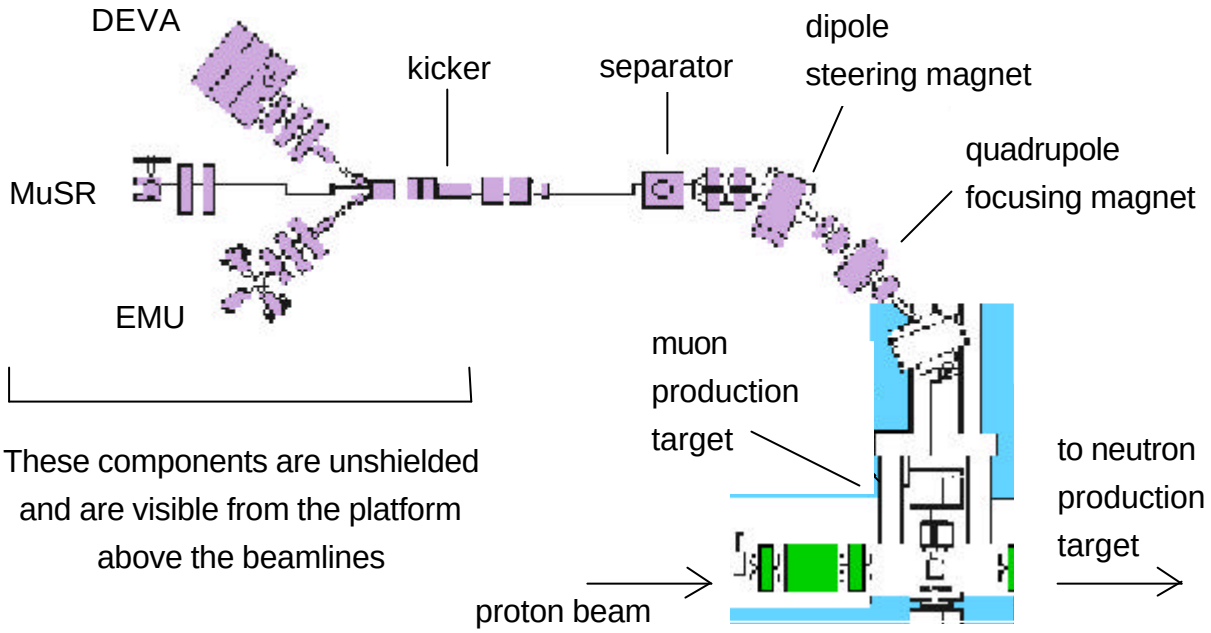


Figure 1. ***Layout of the ISIS muon beamlines.***

1. Introduction

This User Guide is intended to be a practical manual to help users of MuSR set up and run an experiment on the instrument. It contains details of all the main procedures, but if there are things you are unsure about always check with your local contact or the instrument scientist.

1.1 Setting up an experiment

There are certain standard procedures common to most of the experiments run on MuSR. Before beginning to take data, the following must be considered:

- correct instrument geometry (see section 2)
- operation of sample environment (see section 3)
- correct magnetic field for
  (a) compensation of the Earth's field,
  (b) calibrations,
  (c) measurements
  (see section 4)
- appropriate beam size, event rate and steering (see section 5)
- use of computing facilities for data acquisition and analysis (see sections 6-8)

Section 9 gives details of other elements of the muon beamline and spectrometer which the user should be aware of, and section 10 is a brief guide to what to do when things don't seem to be working. Further sources of information and details of how to contact people within the facility are given in section 11.

1.2 The MuSR area interlocks

1.2.1 Closing the area

The blocker which prevents muons entering the MuSR area can only be raised once the area interlocks are complete. For this to happen:

1. Close the gate which allows access above the spectrometer on the top of the MuSR platform, remove its key and insert into the key box to the right of the lower area door. Turn the key clockwise.
2. Check that no-one is inside the MuSR area. Press the search button (situated on the far side of the spectrometer) and close the area door and remove the key from the lock (turning anticlockwise). Insert this key into the key box to the right of the door, turning it clockwise.
3. The key box should now be full. Remove the bottom right hand key and insert it into the green box to the right of the key box, turning it clockwise.
4. Check that the Helmholtz magnet interlock key below the blocker raise / lower buttons is in the vertical position (see section 4.3).
5. The blocker can now be raised: press the red raise button and keep it pressed until the blue area lights come on and the blocker has stopped moving.

1.2.2 Entering the area

To enter the MuSR area

1. If you require the main Helmholtz coil field to not be set to zero, check that the key below the blocker raise / lower buttons is in the override (horizontal) position (see section 4.3).
2. Lower the blocker by pressing and holding the green button. The area lights come on once the blocker is down.
3. Remove the key from the green box by turning it anticlockwise, insert it into the bottom right position on the key box and turn it clockwise.
4. Remove one of the keys (the two left-most keys on the top row are often the easiest) from the key box and insert it into the door lock. Turn it anticlockwise. The door can now by opened by removing the locking bolt.
5. If it is necessary to open the gate on the MuSR platform, remove a second key from the key box and insert it into the gate lock, turning it clockwise.

2. The MuSR spectrometer

Positrons from the decay of muons implanted into the sample under investigation are detected using scintillation detectors. MuSR contains 64 such detectors, each consisting of a piece of plastic scintillator joined by an acrylic light-guide to a photomultiplier tube. The detectors are arranged in two arrays around the sample position on a cylinder concentric with the coils of the main Helmholtz magnet.

The detector arrays and Helmholtz coils can be rotated on their support platform about a vertical axis. When the spectrometer is in longitudinal geometry, the Helmholtz coils provide a field (of up to 2500 G) which is parallel to the initial muon polarisation direction. Rotating the spectrometer through 90^0 in a clockwise direction looking from above puts in into transverse geometry, in which the Helmholtz coils provide a field which is perpendicular to the initial muon polarisation direction. In this case, fields of up to about 600 G are useable, limited by the frequency response caused by the finite width of the muon pulse (see section 4.3.1).

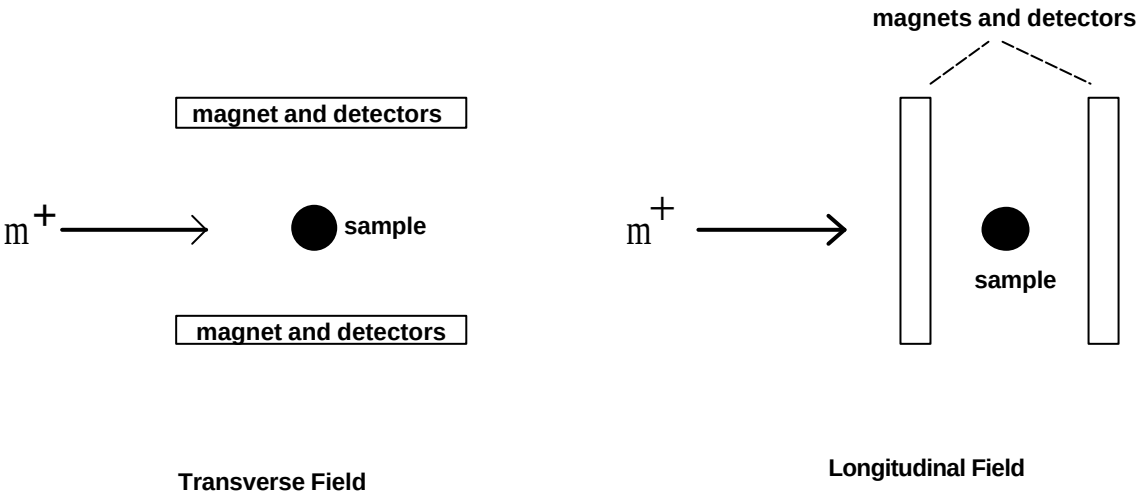


Figure 2. ***Field and detector arrangements in the two MuSR geometries***

In the longitudinal case, one detector array is forward of the initial polarisation direction, and one is backward. Looking upstream (i.e., anti-parallel to the muon momentum, parallel to the initial polarisation direction), the detectors are numbered as below.

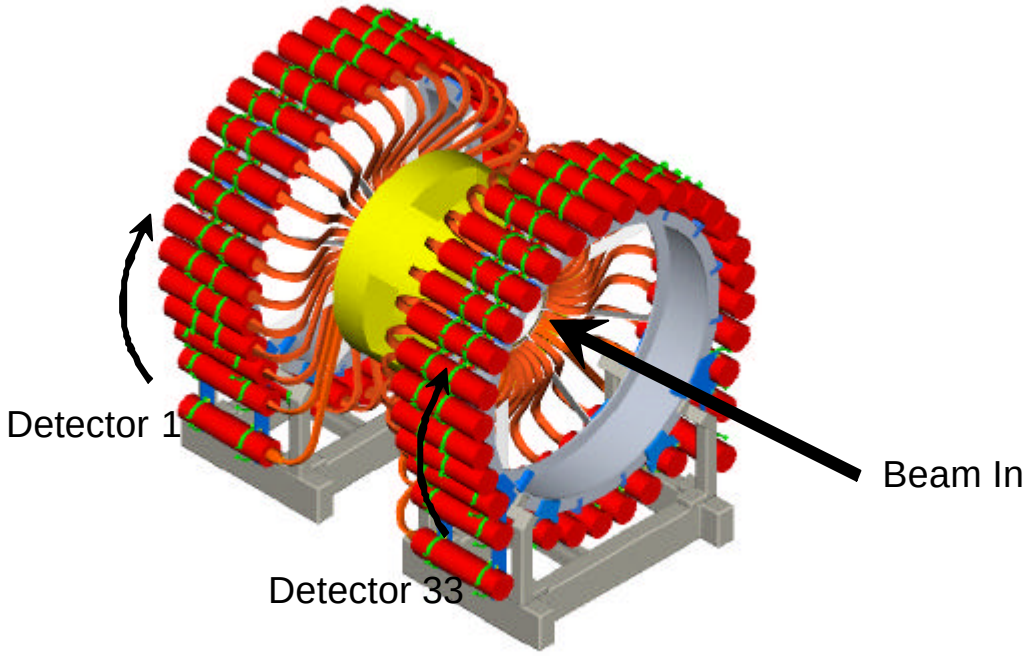


Figure 3. ***MuSR detector numbering***

In order to form a longitudinal forward-backward grouping, detectors 33-64 are summed to form the forward set, and detectors 1-32 summed for the backward set.

In the transverse case, the two detector arrays are perpendicular to the initial polarisation direction. A suitable way of grouping the detectors in this case is in four groups of eight: top (17-24 + 49-56), bottom (1-8 + 33-40), forward (9-16 + 57-64) and backward (25-32 + 41-48). These sets can be analysed separately, or further arranged into forward-backward sets (top-bottom, forward-backward).

MuSR can be rotated between transverse and longitudinal geometry in about 30 minutes. However, **it is important that an instrument scientist be present when the rotation is carried out**: careless actions during the rotation can damage the photomultiplier tubes or puncture the windows in the beam line or dilution refrigerator.

3. Sample environment

The following sample environment equipment is available on MuSR:

Equipment	Temperature Range
Dilution refrigerator, TBT	40 mK - 4.2 K
Dilution refrigerator, OI	40mK – 300K
Sorption cryostat	350 mK - 50 K
Oxford Instruments Variox cryostat	1.6 K - 300 K
'Orange' cryostat	1.6 K - 300 K
Flow Cryostat	4K-400K
Cryofurance Cryostat	6K-600K
Closed cycle refrigerator	12 K - 400 K
Furnace	300 K - 1000 K

Generally, the choice of sample environment will have been made several weeks before the start of the experiment and the equipment will have been prepared by the ISIS sample environment (SE) group. Although the SE group will help in the preparation of cryostats, they cannot be expected to provide support 24 hours a day and users should therefore be able to change samples and temperatures unaided.

The spot from the laser mounted on the MuSR area wall is close to the correct beam position and should be used as a guide for positioning samples in the CCR. Cryostats should be inserted into the beamline with the laser spot as close to the cross on the back of the cryostat tail as possible, and the spot should fall on the centre of the 12-pin Jaeger connector on the furnace stick when it is in the correct position.

3.1 Dilution refrigerator

Users of the dilution refrigerator (DR) are expected to arrive at ISIS at least 24 hours before the start of an experiment to work with the local contact mounting a

sample and starting the precooling process. This takes place out of the beam during the previous users' beam time. Once the DR is prepared it has to be lowered into the beam by a licensed crane driver.

3.2 Sorption cryostat

Users of the sorption cryostat are expected to arrive at ISIS at 24 hours before the start of an experiment to work with the local contact mounting a sample and starting the precooling process (to 4K). This takes place out of the beam during the previous users' beam time. Once the sorption cryostat is prepared it has to be lowered into the beam by a licensed crane driver. There is a separate manual describing the operation of the ^{3}He sorption cryostat.

3.3 The Oxford Instruments Variox cryostat

The Oxford Instruments 'Variox' cryostat is a replacement for the MuSR Orange cryostat, with faster cool-down time and lower He consumption rate. Its principles of operation are very similar, with the exception that the Variox requires continuous pumping to promote He flow through its capillary, whereas the orange cryostat used the pressure inside the He bath to achieve this above 4.2K.

The cryostat will have been prepared off-beam by a member of the ISIS sample environment team. It must be craned into place on the beam line only by a licensed crane operator. Three spacers fit over each of the cryostat resting points on the platform above the beamline to position the cryostat at the correct height.

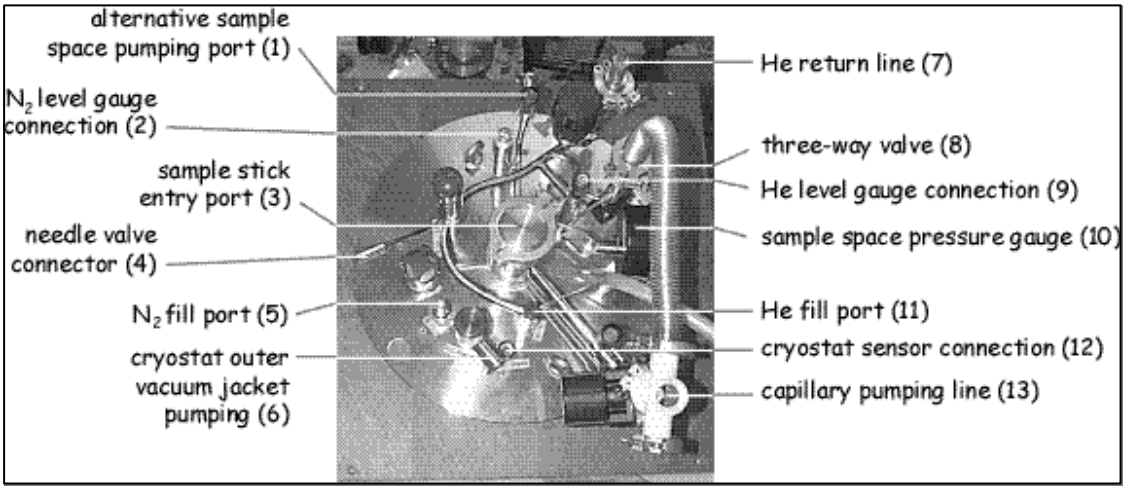


Figure 4. ***The top of the Oxford Instruments cryostat***

The cryostat is controlled from the Oxford Instruments ITC503 temperature controller labelled 'MuSR Variox'. Once in place above the instrument, the cable from channel 1 of the patch panel should be connected to the sensor port on the cryostat (12), and that from either channel 2 or channel 3 can be connected to the sample stick (check the number on the stick to know which channel is appropriate). The needle valve motor drive lead on the cryostat (4) is also connected to the appropriate cable from the patch panel (V1). The He return port on the cryostat (7) is connected to one of the return panels on the cage wall, and the 25 m^3/hr rotary pump is connected to the port marked 'capillary pumping' (13). The He (9) and N_2 (2) level meters are connected to the Oxford level metre gauge.

Below is a brief guide to operation of the blue cryostat. More detailed information about filling with helium and changing a sample can be found in the following RAL reports:

- *Use of cryogenic liquids on ISIS instruments*
  J Chauhan, A V Belushkin and J Tomkinson, RAL-92-041
- *Changing a sample on ISIS instruments*
  J Chauhan, A V Belushkin and J Tomkinson RAL-93-006

There is also an ISIS video on cryostat operation; this can be viewed in the users' coffee area near the Data Analysis Centre.

3.3.1 Removing a sample

1. Ensure the cryostat temperature is greater than 25 K; too low a temperature, and any liquid helium that's been pulled through the capillary could boil rapidly; too high a temperature could cause He gas to diffuse through the Mylar window into the outer vacuum space.
2. Ensure the cryostat is connected to the He return panel, or that a non-return valve is fitted to the He outlet (7).
3. Close the valve to the pump on the capillary line (13).
4. Fill the sample space with He by turning black 3-way valve (8) downwards. Wait until the flow meter on the He return line registers flow again.
5. Remove the sample stick quickly but smoothly by undoing the Klein flange. Cover the sample space with the blanking flange. Return the 3-way valve (8) to its horizontal position.
6. If the cryostat is to be left for a time without a sample present, pump the sample volume (via the 3-way valve (8), turned to upwards position, using the rotary pump connected to the port above the valve).

3.3.2 Loading a sample

1. Ensure the sample stick is completely dry before inserting it into the cryostat.
2. Ensure the cryostat is at about 25 K.
3. Ensure the cryostat is connected to the He return panel, or that a non-return valve is fitted to the He outlet (7).
4. Fill the sample space with He by turning the black 3-way valve (8) downwards. Wait until the flow meter on the He return line registers flow again.
5. Remove the blanking flange and introduce the sample stick quickly but smoothly (3).
6. Pump the sample space (via the 3-way valve (8), turned to its upwards position) to ~1 mbar (the gauge on the top of the cryostat (10) reads the sample space pressure) using the rotary pump.
7. Turn the 3-way valve (8) to its downwards position to add He to the sample space, and pump again to about 1 mbar.
8. Add He to the sample space again and pump until the sample space gauge (10) reads 20 mbar. This is the correct exchange gas pressure.

3.3.3 Operation above 4.2 K

Operation above 4.2 K is fully automatic once the 25 m^3/hr pump has been set to pump He gas through the capillary. Set-points can be entered using the `settemp` command in OpenGENIE, and the ITC503 controls the heater and needle valve settings.

3.3.4 Operation below 4.2 K

A different procedure is necessary for operation below 4.2K, as the ITC503 temperature controller is unable to set the gas flow through the cryostat automatically for these temperatures. To get to base temperature (about 1.6K) use the following procedure:

1. Issue the command `blue_lt` in the OpenGENIE window.
2. Manually check that the set-point in the ITC503 is zero by pressing the 'SET' button.
3. Connect the 0-1000 cm^3/min flow gauge to the Rootes pump exhaust.
4. Manually adjust the gas flow on the ITC503 until the pump exhaust flow rate is about 450 cm^3/min (you need to be in 'LOCAL' mode on the ITC503 to do this).
5. The temperature should rapidly drop to below 2K.
6. Enter set-points as normal up to about 5K.

To return to automatic operation above 4.2K

1. Issue the command `blue_ht` in OpenGENIE window
2. Disconnect the flow meter from the Rootes pump exhaust.
3. Set the desired temperature within MCS.

The ITC503 should go back to automatic control of the gas flow.

3.3.5 Filling with Helium

The time for which a helium fill will last is greatly dependant upon the type of experiment being carried out. Sustained running at high temperatures or repeatedly cycling between high and low temperatures can require a fill every twelve hours. At the other extreme, a helium fill can last for well over twenty-four hours if running at a near constant low temperature. As a general guide, the helium level should be checked at least once every twelve hours (don't forget to fill with nitrogen too).

The following procedure should be followed to fill the cryostat. Users should note that two people are required. Use the flexible transfer tube on the side of the MuSR platform.

1. Set the He level gauge for high readout rate.
2. Open the by-pass valve on the He return line.
3. Vent the helium storage dewar by opening the red valve. Open the top valve on the dewar then close both red and green valves.
4. Slowly lower the longer end of the transfer line into the helium storage dewar. The other end of the transfer line will require support. The fitting on top of the storage dewar should be tightened to prevent gas escaping.
5. Helium gas should immediately begin exhausting from the transfer line. After approximately one minute cold gas will be felt and a short while later a plume will form.
6. Once a plume is observed quickly insert the transfer line into the helium fill port on the cryostat (normally closed by a brass plug). Note that if refilling with helium the transfer line should only be pushed approximately halfway into the cryostat dewar.
7. Helium transfer should now take place, the process taking a few minutes (for a refill).
8. During the transfer an over-pressure must be maintained in the helium storage dewar using a He gas line or bladder attached to the red port.
9. When the helium level gauge measures 100% stop the transfer by releasing the pressure in the storage dewar, typically by removing the gas line / bladder and opening the red valve. Remove the transfer line from the cryostat and replace the brass plug, ensuring it has been fully tightened (the fitting may require heating). Remove the transfer line from the dewar and open the green valve.
10. Leave the helium storage dewar with both the top valve and the red valve shut and the green valve open.
11. Switch the helium level gauge to low readout rate.
12. When the He recovery flow has returned to less than 10 l/min close the He recovery by-pass valve.

3.3.6 The Oxford ITC503 Temperature Controller

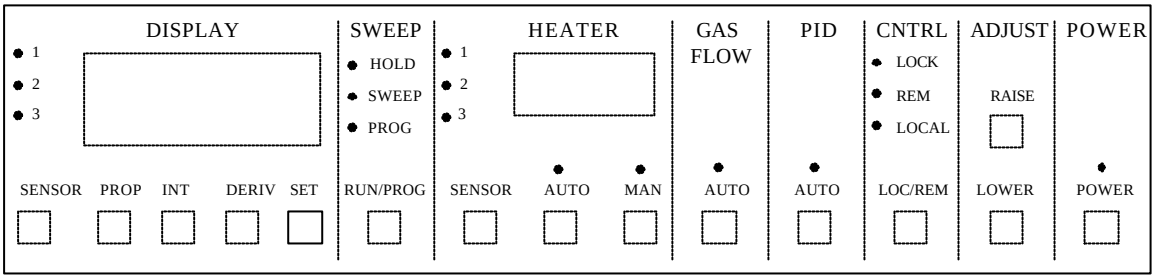


Figure 5. ***The front panel of the ITC5 temperature controller***

A diagram of the front panel of the ITC503 is shown below. Two types of interaction with the controller are possible: inspecting the present settings while running the controller in automatic mode, and switching to manual control to adjust parameters.

Inspecting the controller (automatic operation)

To guard against inadvertently altering settings, the user should ensure the controller is in remote mode (i.e. the remote light is on) before inspecting any parameter. Pressing the 'LOC/REM' button toggles the controller between local and remote modes of operation.

Requirement	Action
View temperature of sensor 1, 2 or 3	Press the ‘SENSOR’ button until the LED corresponding to the particular sensor is alight.
View current set temperature	Press the ‘SET’ button.
View current heater voltage	Press the ‘AUTO’ button under ‘Heater’.

After checking the parameter ensure that the controller is still in the required mode of operation, usually with the heater in automatic mode.

Manually adjusting parameters

Switch the controller to the local mode of operation by pressing the 'LOC/REM' button. Note that SECI will periodically return the controller to the remote mode.

3. Sample Environment

Requirement	Action
Adjusting the set temperature	Press the ‘SET’ button with either the ‘RAISE’ or ‘LOWER’ buttons under ‘ADJUST’.
Adjusting the heater voltage	Press the ‘MAN’ button under ‘Heater’ simultaneously with either the ‘RAISE’ or ‘LOWER’ buttons under ‘ADJUST’. The voltage can be read. Note that the heater sensor is always number one.
Adjusting Gas Flow	Press the ‘AUTO GAS’ button simultaneously with either the ‘RAISE’ or ‘LOWER’ buttons under ‘ADJUST’.
Adjusting PID’s	Press either ‘P’, ‘I’ or ‘D’ button simultaneously with either the ‘RAISE’ or ‘LOWER’ buttons under ‘ADJUST’.

3.4 Orange cryostat

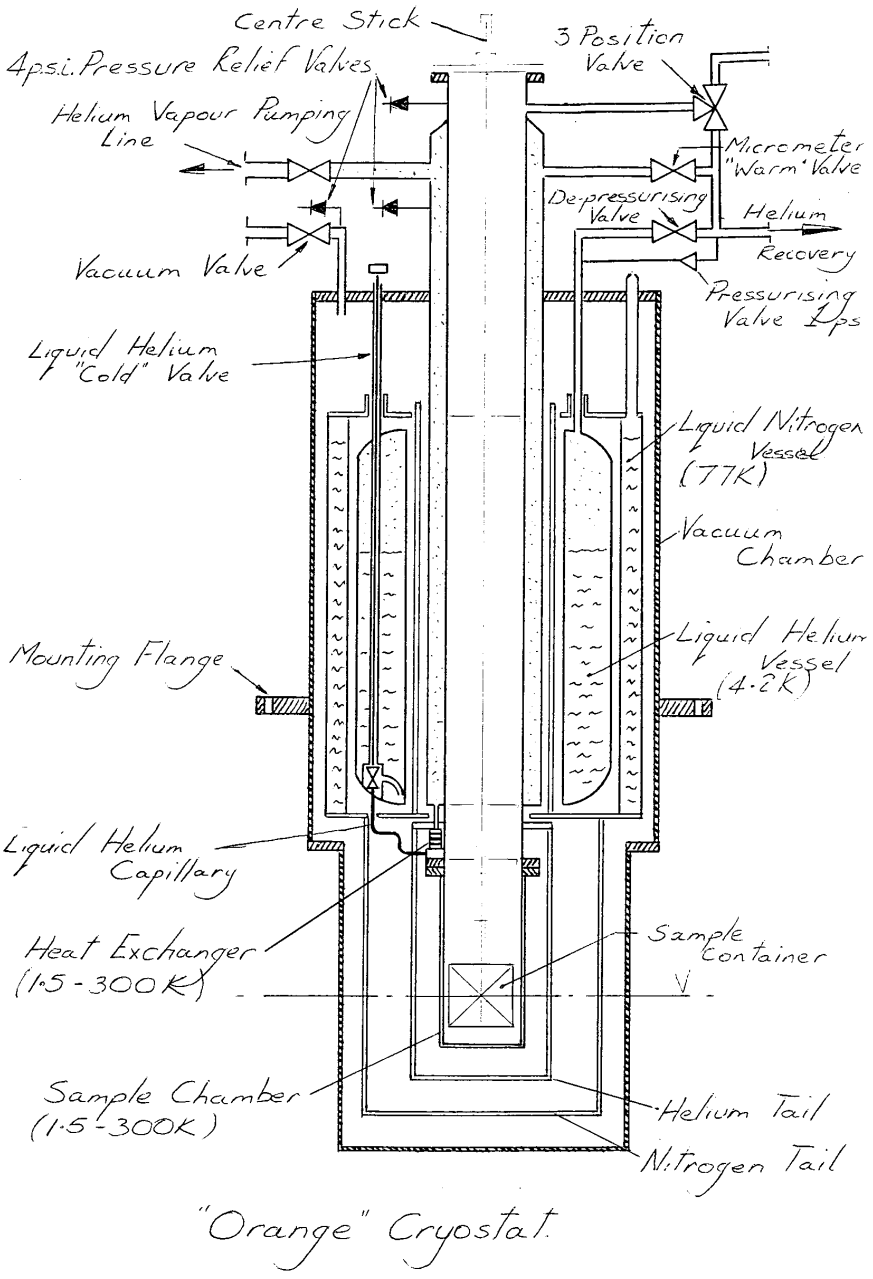


Figure 6. ***The Orange cryostat***

Operation of the orange cryostat is very similar to that described above for the Oxford Instruments Variox. The OC is controlled by the ITC5 temperature controller labelled ‘MuSR orange’ on the platform above the spectrometer.

3.4.1 Removing a sample

Instructions are as for the Variox – the black three-way valve on the top of the Variox has the same operation as the blue 3-way 'Hoke' valve on the top of the orange cryostat.

3.4.2 Loading a sample

Again, the procedure is the same as for the Variox cryostat.

3.4.3 Cooling the cryostat to 4.2 K

Operation is similar to the Variox in principle; however, the gas flow through the cryostat is controlled manually using the 'cold' valve (valve 4 in the orange cryostat diagram) and the 'warm' valve (valve 6). The cold valve controls a needle valve which allows liquid helium from the main reservoir into the annular space via a capillary and heat exchanger. To close the cold valve it should be turned clockwise. Be careful not to over-tighten it, otherwise the needle may be damaged.

1. Open the cold valve (rotate it between half and one turn anti-clockwise from when it first 'bites').
2. Open the warm valve until the He flow rate is at maximum on the He return line meter (10 l/min).
3. Wait for the cryostat to cool to the desired temperature.
4. Close the warm valve until the He flow rate is 4-5 l/min.

3.4.4 Cooling the cryostat below 4.2K

This requires the He brought through the needle valve to be pumped using the large 'Roots' pump. The cryostat temperature must be below 50 K before pumping starts.

1. Connect the Roots pump to the He pumping valve (valve 3) of the cryostat.
2. Close the cryostat cold and warm valves fully.

3. Make sure the cryostat valve 3 is closed. Disconnect the flow meter from the Roots pump outlet if one is attached. Turn the Roots pump on (press both green buttons) and open the big isolation valve on the pump to evacuate the line up to the cryostat. Wait until the gauges on the pump read zero.
4. Slowly open valve 3 of the cryostat. Wait for a few minutes, then reconnect the flow meter to the Roots pump outlet line. Open the fine control of the cold valve *very slightly*, until the pump flow meter is reading maximum.
5. When the cryostat has reached the required temperature, close the cold valve until the pump flow meter is reading <4 l/min (this may mean winding the valve control until it is fully closed).

3.4.5 Filling with Helium

Again, this is very similar to the Variox cryostat. A different He level gauge is used for the orange cryostat – you'll need to switch this on before filling, and to turn it off afterwards. You need to open the depressurising valve on the He return line on the cryostat (valve 8) before filling – remember to close it again afterwards.

3.4.6 Care of the cryostat when not in use

The cryostat can be left in its support frame, either on the MuSR platform or at ground level, when not immediately required. In this case, users should leave the cold and warm valves open a very slight amount to allow a small flow through the cryostat; this reduces the chance of the cryostat blocking, but does not use large amounts of helium. **Users should still remember to check the cryogen levels once every twelve hours and refill as required.**

3.4.7 Additional notes

- At low temperatures, the exchange gas in the sample volume may have condensed, leading to poor thermal contact to the annular space. The exchange gas pressure can be monitored using the meter on the small rotary pump (with the pump valve closed, and the blue Hoke valve turned upwards). If the pressure has dropped, add more gas by turning the Hoke valve to its downwards position for an instant, and then pumping the sample space to the required pressure.
- If oscillations in the temperature of the cryostat are observed, the exchange gas pressure may be too high. Try pumping the exchange gas to 5-10 mbar.

- When cooling, the He flow rate through the return line should be controlled by the warm valve setting. If opening the warm valve a small amount doesn't increase the flow rate, open the cold valve until the rate increases and then close the warm valve to achieve the required rate.
- When the cryostat is at the required temperature, the He flow rate should be reduced to about 4-5 l/min. But this rate should be monitored for the first hour or so after cooling as it will be affected by any liquid helium which has entered the annular space. The flow rate may change as this liquid boils off and may become too low when the annular space no longer contains liquid.
- At very low temperatures, an offset between the sample and cryostat thermometers can be expected owing to condensation of the exchange gas in the sample space.

3.5 Flow Cryostat

The Flow crystats are controlled using an ITC5. The temperature range is 4 to 400K for the normal flow cryostat and 6K-600K for the cryofurnace flow cryostat.

3.5.1 Sample holder

This cryostat can use the same sample holders as the EMu "Blue" cryostat: 37mm square with hole spacing 30mm. The internal diameter of the cryostat is 43mm.

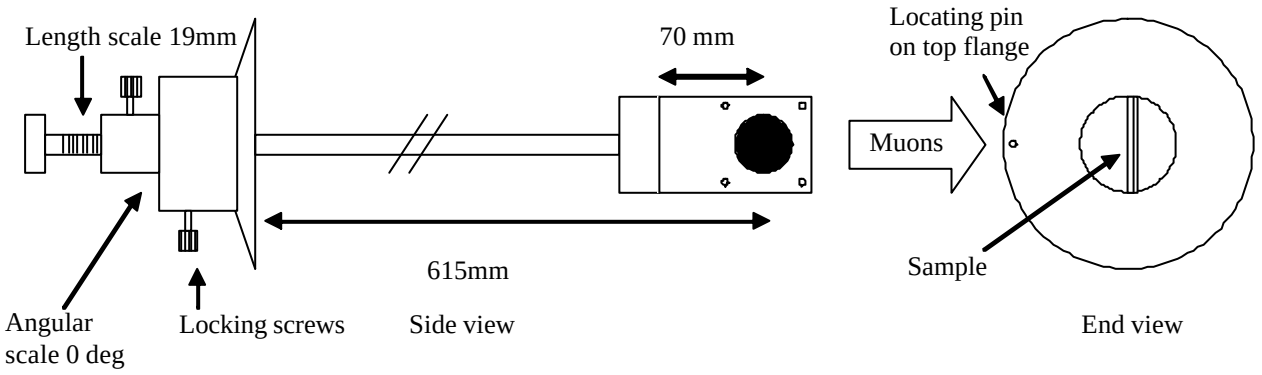


Figure 7. ***The flow cryostat centre stick.***

With the standard blade and sample holder, the length from the bottom of the copper block to the sample centre is 70mm and the top adjustment should be set to 19mm. If a non standard sample mount differs from 70mm, adjust the top scale by the same amount.
For the standard blade, set the angle to 0 degrees. The muon arrival direction is in line with the locating pin on the top flange and the sample plate should normally be perpendicular to this. You can rotate the sample relative to the beam if required by your experiment, either now or when in the cryostat.

3.5.2 Installation

The cryostat fits into a support cage. This cage should be mounted above dizital and the cryostat lowered into the support cage (**use of the crane requires a crane drivers license**). Install it with the transfer tube connection in the "downstream" direction. The locating pin on the top flange will be towards the beam.

Use the appropriate ITC5 temperature controller for the cryostat and connect through the patch panel.

Start pumping the OVC using a turbo pump.

3.5.3 Connections

- Cryostat sample space port should be connected to a T-connector which is connected to He gas, gauge and rotarty pump.
- Cryostat heater/thermometer to ITC channel 1, the stick thermometer to ITC channel 2 (stick A) or 3 (stick B) and the transfer tube needle valve to ITC Aux. Out, through the patch panel
- Transfer tube gas outlet (at the top of the dewar leg) to the pumping box via a long plastic tube
- Connect using the switch box.

3.5.4 Inserting the stick

The sample can be changed when the cryostat is cold, but heat it up to >25K first.

- Let the sample space up to 1 atm with helium.
- Insert the stick: the pin on the stick flange should locate into the hole in the flange on the cryostat.
- Pump the sample space, purge two or three times with helium, and set the exchange gas pressure to 15 mbar.

3.5.5 Cooling

- Check that the PTFE sealing washer is present on the cryostat end of the transfer tube.
- Connect the needle valve cable. Turn the ITC5 on. This initialises the valve.
- Open the needle valve fully: press and hold "Gas Auto" and then press "Raise". Check it stays in Manual (light off).
- Check with your local contact that the dewar has the helium level probe installed.
- Insert the leg of the transfer tube in the dewar. **Be very careful not to bend the transfer tube**. In practice the tube will need to be almost fully inserted into the dewar before the transfer tube can be inserted into the cryostat. Reduce pressure in the dewar as required with the red valve.
- Put the transfer tube into the cryostat and tighten the locking nut. Turn on the diaphragm pump. Open the valve on the pumping box. There should be a very small flow.
- After about 5 minutes the flow should increase as liquid reaches the cryostat, and the temperature will start to fall.
- The Green valve on the dewar should be open and the Red valve closed during operation.

If the cryostat is still not cooling after 20 minutes, the tube may be blocked with ice or solid air:

- Remove the transfer tube from the cryostat and dewar.
- Warm both ends with the hot air gun.
- Blow clean helium gas through it – use a piece of rubber tube over the cryostat end.

3.5.6 Removing

3. Sample Environment

- Warm the cryostat to 25K or above.
- Ensure the needle valve on the transfer tube is open (set the ITC5 to Local, then press Gas Flow and Raise) then shut the valve on the pumping box. The pressure should rise rapidly to 1 atm. If it doesn't, check with your local contact.
- The transfer line can then be removed. **Be careful not to bend either of the legs**. If the cryostat will be used again during the experiment the transfer line may be left in the dewar with the needle valve **closed**. Be sure to fit the protective tube over the free end of the transfer line.
- Unplug all the electrical leads from the cryostat. Close the sample space tap and disconnect the sample space pumping line.
- Close the OVC value and switch off and disconnect the turbo pump.
- The cryostat and lift it out.
- Remove the frame

3.6 Closed-cycle refrigerator (CCR)

The CCR is controlled using the Eurotherm TC820 controller in the rack in the MuSR area. Check that both data switches (in the MuSR area and in the back of the MuSR cabin) are at the CCR position.

Users will need to know how to change the sample in the CCR. In preparation for a sample change the temperature should be set to 300K and the compressor turned off. Once the CCR has reached a reasonably high temperature (>270 K) the following procedure can be carried out to remove the sample:

- Close the large isolation valve on the top of the pump
- Switch off the pump
- Open the vent valves to vent the pump and CCR
- Swing the CCR out from between the magnet faces
- Remove the CCR tails and unscrew the sample plate from the copper block

TAKE CARE NOT TO BEND THE RhFe THERMOMETER LEADS

After mounting a new sample, close and restart the CCR in the following way:

- Dry the CCR, heat shield and outer tail (use a heat gun, but be careful not to heat the thermal fuse). Replace the tails, checking that the windows are aligned and facing the muon beam pipe window.
- Swing the CCR back into place taking care not to knock the calibration coils.
- Check the vent valves are closed.
- Start the vacuum pump and switch on the Pirani gauge.
- Slowly open the large pump isolation valve.
- When the Pirani gauge reads $<10^{-1}$ Torr the Penning gauge automatically switches on.
- Below $5x10^{-3}$ Torr the compressor may be switched on by turning the switch on the front the central compressor (outside the area) from 0 to 1.

The compressor must be left on for all sample temperatures, including those above room temperature.

There is a thermal fuse on the heater lead inside the CCR to prevent excessive heating. Users can check that the heater is working by heating to slightly above room temperature before starting to cool. If the heater does not work then check the Eurotherm trip.

3.7 Furnace

The muon furnace is designed to allow μSR experiments to be carried out on the EMU and MuSR spectrometers (with MuSR in either longitudinal or transverse orientation) at temperatures from room temperature up to 1000 K.

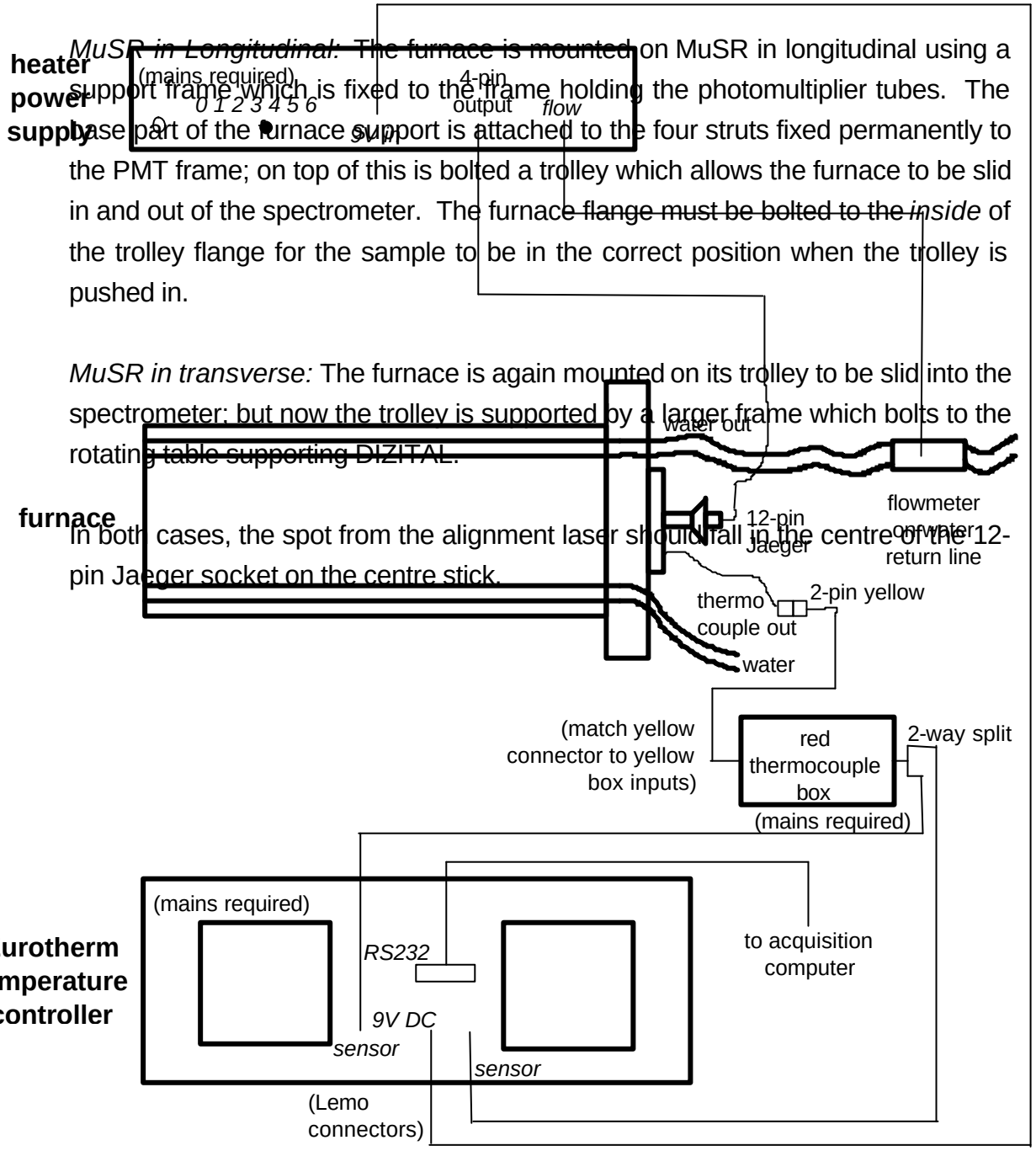
It consists of an outer vacuum jacket with a thin (30 μm) titanium window to allow muon entry, into which a centre stick is inserted which holds the sample and heating element. The sample temperature is monitored by a thermocouple sensor mounted on the sample plate, and controlled by a Eurotherm temperature controller; this in turn is monitored and controlled from MCS. The outer body of the furnace is cooled by water flowing through external pipes and around the muon entry window. Two heat shields (also 30 μm Ti) between the entry window and the sample position also reduce heating effects on the furnace window. Zero field should be reset after the furnace support is mounted.

3.7.1 Sample mounting

The furnace centre stick allows samples up to 40 mm x 40 mm to be mounted, and the Ti mounting plate is drilled to allow sample holders of the size and shape used on the EMU blue cryostat to be fixed (M3 screw holes arranged in a square with 30 mm between their centres). Titanium sample holders are available for use with powdered samples. These consist of a Ti plate with a depression into which a powder can be packed and over which a thin Ti window can be fixed using a clamping ring. Ti screws and thin Ta wire are available for attaching a sample holder to the mounting plate. Ti produces a negligible depolarisation of the muon signal at furnace temperatures and so is suitable for use as a mask material. Thick windows in front of a sample should be avoided as the four Ti foils (including the one on the sample mount) reduce the muon penetration to less than 70 $mg.cm^{-2}$; a range curve a taken in the furnace is given in figure 8, section 3.8.

It should be noted that Al and Ag sample holders are NOT suitable for use in the furnace owing to the low melting point of Al; similarly, users should consider whether their sample has a melting or decomposition temperature within the reach of the furnace and take suitable precautions!

3.7.2 Mounting the furnace on the instrument



MuSR in Longitudinal: The furnace is mounted on MuSR in longitudinal using a support frame which is fixed to the frame holding the photomultiplier tubes. The base part of the furnace support is attached to the four struts fixed permanently to the PMT frame; on top of this is bolted a trolley which allows the furnace to be slid in and out of the spectrometer. The furnace flange must be bolted to the *inside* of the trolley flange for the sample to be in the correct position when the trolley is pushed in.

MuSR in transverse: The furnace is again mounted on its trolley to be slid into the spectrometer; but now the trolley is supported by a larger frame which bolts to the rotating table supporting DIZITAL.

In both cases, the spot from the alignment laser should fall in the centre of the 12-pin Jaeger socket on the centre stick.

Figure 8. ***Furnace connections***

3.7.3 Connections

Once the furnace body, with centre stick in place, has been mounted on the instrument connections as shown in the diagram below are made.

1. The lead from the sample thermocouple (thermocouple B) is connected via a red lead to the yellow terminal of the red thermocouple box. A two-way splitter is connected to the white output terminal of the box to feed two leads which attach to the sensor inputs on the Eurotherm controller via Lemo connectors.

2. The 12-pin Jaeger connector on the centre stick is connected to the 4-pin output on the heater power box.
3. The 9V DC output of the Eurotherm is connected to the 9V input on the heater box via Lemo connectors.
4. The flowmeter signal wire is connected to the flow input on the heater box via a Lemo connector.
5. The RS232 link on the Eurotherm is connected to the RS232 cable in the area (use the one normally devoted to the CCR Eurotherm). Check that the two sample environment data switches are in the CCR position.
6. The two cooling water hoses are connected to the two tubes on the furnace body (it doesn't matter which way round). The hose with the flow sensor must then be connected to the water return socket on the area wall, and the other hose connected to the water output socket. Don't forget to turn the cooling water on - there are two taps, one on the feed line and one on the return line.
7. The furnace pumping port on the centre stick is connected to the rotary/turbo pump set in the area via a 4-way cross-piece which also allows connection of a pressure gauge and a valve to admit He exchange gas. It is useful to ensure that there is a valve capable of isolating the furnace in place between the furnace and the cross-piece. The pump set used should be one reserved for a furnace to avoid contaminating a clean set.

The flow sensor on the water return line is designed to cut off the heater power to the furnace if the flow falls to too low a level. The LED on the heater box by the flow input goes out if the heater has been tripped in this way.

3.7.4 Eurotherm set-up

Normally, a dedicated Eurotherm is provided which will be already set up for furnace use. However, in the event of a CCR Eurotherm having to be used to control the furnace, please ask your local contact to configure it for use with thermocouple sensors. For full details of operating a Eurotherm, see 'The Users Guide to the Temperature Controllers' by H.M. Shah (copies are in the filing cabinet in the EMU cabin).

3.7.5 Controlling the furnace

Exchange gas within the furnace vacuum jacket is necessary to allow control over the low temperature part of the furnace range (up to about 200 ^{o}C). The rotary/turbo pump set connected to the furnace pumping port can be valved off once a good vacuum has been reached and 20 mbar or so of He gas introduced into the furnace body. This can then be pumped out for high-temperature operation.

There are six different heater power settings (and an off, '0', setting) on the heater box. The table below shows the heater settings, PID and exchange gas values required at different temperatures.

Max. working Temperature °C	Eurotherm Heater Power (%)	Heater box voltage setting	P (%)	I (s)	D (s)	Exchange gas
100	25	2	0.8	70	14	Yes
200	50	2	0.7	70	14	Yes
300	100	2	2.7	125	25	No
400	25	3	4.9	125	25	No
500	100	3	6.2	105	21	No
600	50	4	16	55	11	No
700	50	5	16	35	7	No

These settings have been optimised to achieve the best possible stability. Users wishing to scan a temperature range on a script may be able to find a compromise in the settings that will still achieve reasonable stability, but will allow unattended operation over an extended temperature range. However, please

note the maximum temperature that can be reached for each heater box voltage setting (Eurotherm heater power set at 100%):

Heater box voltage setting	1	2	3	4	5	6
Max. working temperature (°C)	190	380	510	640	700	700

3.7.6 Typical data collection parameters

The wall of the furnace vacuum jacket acts as a degrader in front of the scintillation detectors, preventing the lowest energy positrons from being counted. This has the effect of reducing the count rate (requiring the beam slits to be opened more widely than normal) and increasing the maximum asymmetry (to close to 27% on MuSR). Alpha values close to 1.5 are common owing to the shielding of the backward detectors by the sample mounting plate and heating element. Check with your local contact for correct steering magnet values.

3.8 Temperature control files

Whenever a temperature set-point is sent by OpenGENIE to a temperature controller, various other parameters are also passed to enable the temperature to be controlled. These include the appropriate Proportional, Integral and Derivative (PID) values and the maximum heater power. OpenGENIE reads these values from files which sit in the directory c:\labview modules\mkscript3\muon_temperature.tpar. This file is changed when changing configurations.

Column label	**function**
TLOW and THIGH (or MINTEMP, MAXTEMP)	specify a temperature range for given PID values
CYCLE	Max Power
PROP	proportional value
INT	integral value

DER	derivative value

ACCUR	the temperature range around the set point within which MCS will consider the temperature to be stable
WAIT (or TWAIT)	the length of time (mins) that the temperature must be within the accuracy band before MCS will start a run
TMOUT (or TIMEOUT)	the time after which, even if the temperature has not stabilised within the accuracy band, MCS will start a run anyway
MAXI (fridge only)	controls the heater power range

Occasionally, it is necessary to alter the PID values that OpenGENIE is using. This can be done by editing the appropriate muon_temperature.tpar file (use notpad) and then re-sending the temperature set-point (for Eurotherm/ITC5). Information in the .tpar files is arranged as a table, with columns labelled as in the table above.

3.9 Sample mounts

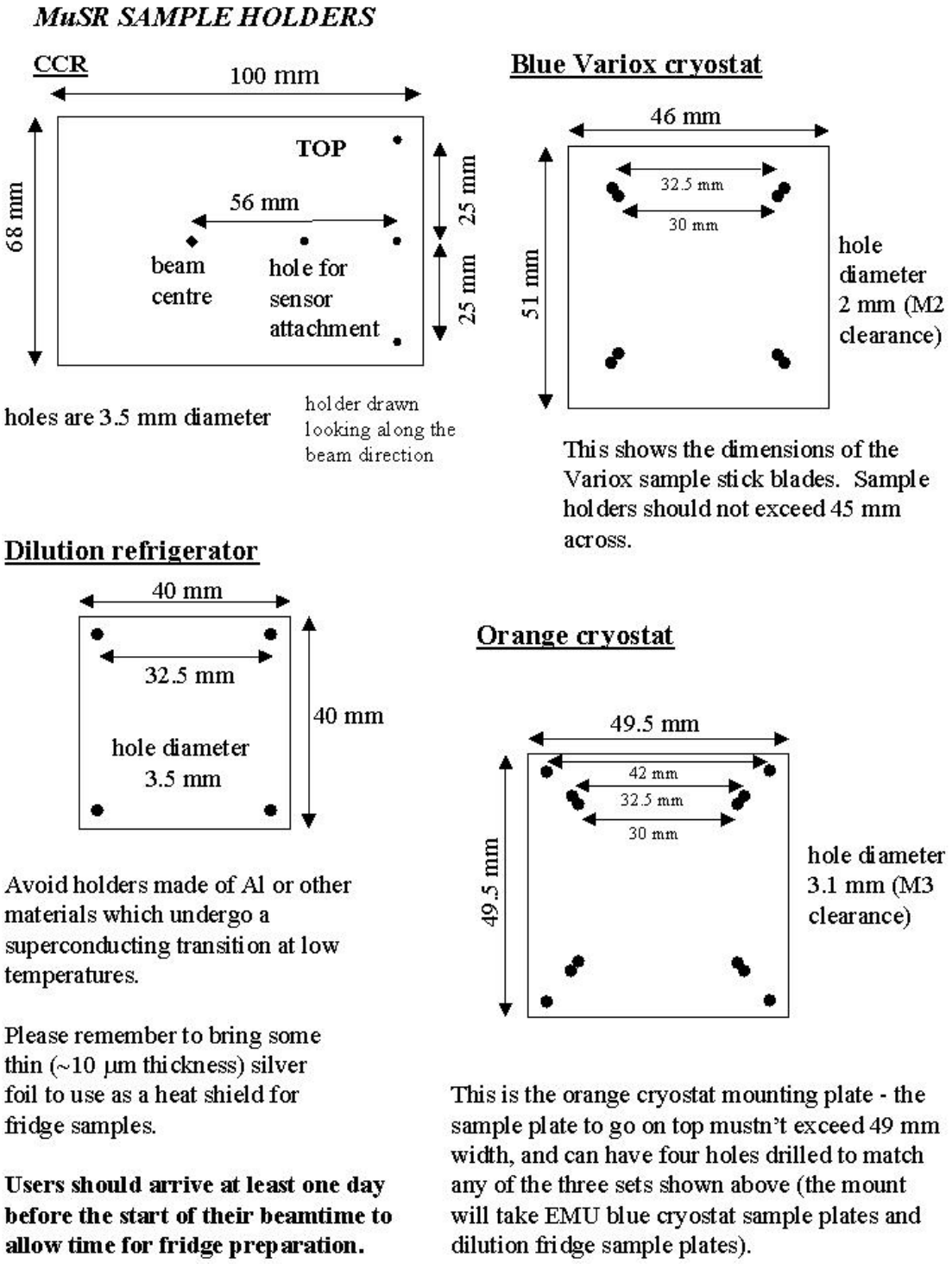


Figure 9. ***MuSR sample mounts***

3.10 Range curve

The muons in the beam hit the front surface of the sample at about $0.25c$ (3.0 MeV) and are then slowed by interactions within the material before stopping. The implantation energy of the muons results in them passing through several hundred microns of material before they come to rest. The actual amount of material traversed and the width of the muon distribution depend upon the material's density - as a rough guide the muon range is roughly 100 mg.cm^{-2} of material i.e. about 1 mm of water, 500 μm of silicon, etc.

Figure 8 below shows the diamagnetic asymmetry (in a 20 G transverse field) as thin titanium foils (thickness about 25μm) are added in front of a thick quartz plate mounted in the MuSR/EMU furnace. Initially a low asymmetry is recorded as all muons are stopped in the quartz where there is an appreciable muonium fraction. Adding more than four titanium foils causes the asymmetry to rise as an increasing proportion of the muons are stopped in the metal (in which all muons thermalise into a diamagnetic state). Full asymmetry is obtained when at least ten foils have been added.

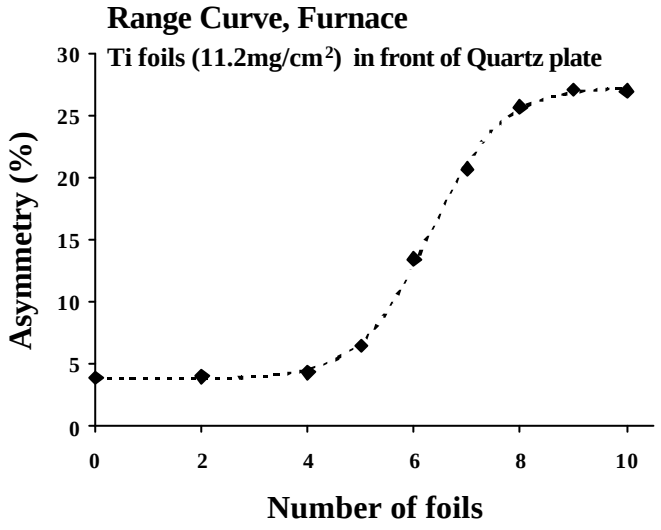


Figure 10. ***Range curve in the MuSR/EMU furnace***

It should be noted that in the dilution fridge additional windows in the cryostat tails reduce the muons' energy significantly before they reach the sample. Any material placed over samples for the fridge should be very thin indeed (10 μm thick silver is used for heat shields) otherwise the muons may not reach the sample.

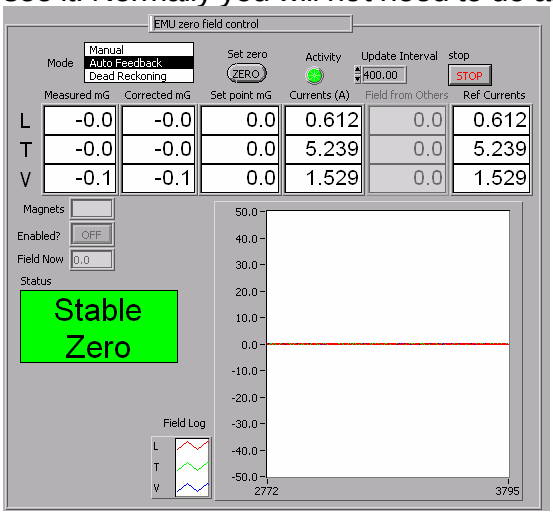
Samples for μSR experiments should be appreciably thicker than the average muon stopping distance. When thin samples are used, sheets of metal or plastic should be added in front of the sample to maximise the signal from the sample and to prevent the muons from passing all the way through. The decision to use either metal or plastic as the degrader will generally depend upon the nature of the sample being studied and the need to create a contrast between the sample and degrader. For samples having a missing fraction, metal is the most appropriate choice (pre-cut 30 μm-thick titanium sheets are available for this purpose) while, conversely, a plastic degrader is ideal for metallic samples.

4. Magnetic fields

4.1 Zero field compensation

Three pairs of orthogonal coils mounted around the sample position are used to cancel the earth's magnetic field. They are powered from the three Iso-tect power supply units (labelled L V and T) in the electronics rack inside the MuSR area. The field is measured using a triple-axis fluxgate magnetometer mounted just below the beamline window and is used to control the currents in the coils. A second probe can be fixed at the sample position and used to check the zero setting – read this on the display with the unit in the rack.

The Instrument PC runs the Labview control program “zerofield v5.vi” which should automatically load and run when SECI starts. Select the “magnets” tab to see it. Normally you will not need to do anything here.



“F0” tells Labview to use the auto zero field controller.
“TF20” selects the TF20 or main magnet returns the currents to manual control of the currents.

Once the field is set to zero remove the probe from the sample position.

If varying the current, on the vi, does not change the field at the sample position or the message “current overload” appears on the PC, check that the coils have been reconnected to the box on the fence between MuSR and EMU. If the field readings remain fixed at about 5000 mG (their maximum) check that neither the T20 coils nor the main Helmholtz coils are on.

The zero field calibration is different for longitudinal vs. transverse setups: change over by using “Go To Longitudinal” or “Go To Transverse” buttons.

4.2 Calibration field

When working in longitudinal geometry it is necessary to start each section of runs (after a sample change or change from CCR to cryostat for example) with a calibration measurement in a transverse field of approximately 20 gauss. These measurements are usually quite short (<5 Mevents) and are often referred to as "T20" runs. Two small coils, which hang either side of the sample, are used to provide a small transverse field. They are powered by a Gossen power supply and controlled by the computer through OpenGENIE with the command `TF20`.

4.3 Applied fields

Magnetic fields are provided using the large Helmholtz coils powered by the Danfysik PSU. This is controlled by MCS via a GPIB interface. The maximum field available on MuSR is 2500 G. The Danfysik is operated as follows:

- Type `lf0` in OpenGENIE; this sets the magnet device to the Danfysik PSU. Set fields using the command `Setmag x`. A read-out of the field is given on the computer screen in the "MAGNET" window. If this is not successful then check interlocks on front panel of magnet power supply.

Whenever the beam blocker is lowered the field generated by the Danfysik is automatically set to zero. It is possible to over-ride this process by carrying out the following procedure:

- Turn the key on the panel by the entrance to the experimental area to "over-ride" **before** lowering the blocker
- Open and close up the area as usual, but return the over-ride key to its original position **before** raising the blocker
- Check there are no red lights illuminated on the Danfysik power supply

If the power supply trips at any time it can usually be restored by reseting the interlocks on the front panel. If this is not successful check the trip switches (see section 9.1)

After selecting a new magnet device, always check that the field set via OpenGENIE has been accepted by the power supply.

4.3.1 Effects of the finite muon pulse width on useable transverse fields

At ISIS the muons are produced in short pulses (about 80 ns wide at half height) and the approximation is usually made that an average arrival time near the centre of the muon pulse can be used as time-zero. This is adequate if the time-scale of the evolution of the muon polarisation is long compared with the width of the muon pulse but leads to difficulties in cases where the evolution is rapid. The effect is seen clearly by considering a transverse field experiment performed at a succession of magnetic fields. At low precession frequencies the polarisation is seen with full asymmetry. As the frequency increases there is an appreciable phase difference developed between muons from the beginning and end of the pulse and the observed asymmetry falls. This is seen in the plot below, produced from the precession of muonium in quartz in low transverse fields (data taken on EMU, although the MuSR response is the same). Even though MuSR will allow fields of up to 2000 G to be applied when in transverse orientation, the low asymmetry limits the useable field to about 600 G (8 MHz).

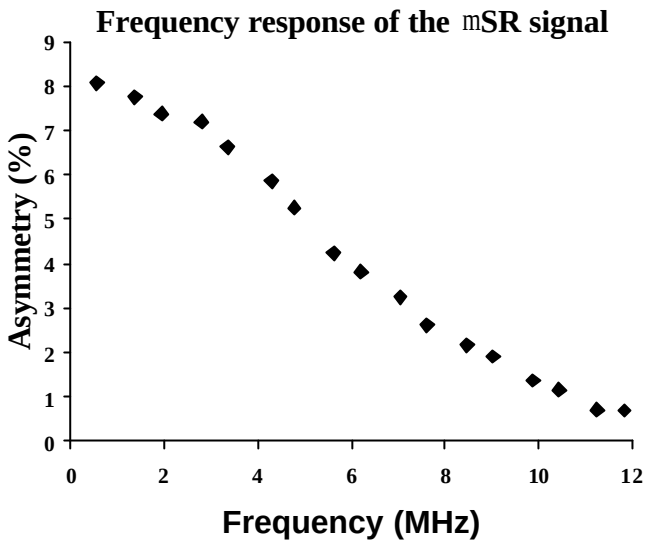


Figure 11. ***Frequency response in transverse fields***

4.3.2 Effects of high longitudinal fields on asymmetry

The asymmetry measured for a large silver plate, mounted in the MuSR CCR, in longitudinal magnetic fields up to 0.25 T, is shown below. As the field is increased there is a small but gradual fall-off in the measured asymmetry, with roughly a 3% reduction at 0.25 T. This change is an artefact that is probably a result of a shift in the value of a caused by the interaction of the magnetic field with both the decay positrons and the photomultipler tubes. Experimental data can be corrected for the effect; however, the precise form of the curve seems to depend on the initial value of α, and you are advised to perform your own calibration and not rely on the curve below.

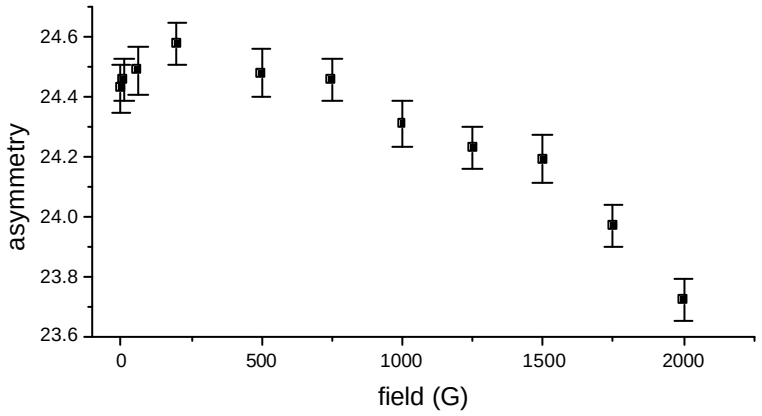


Figure 12. ***Effect of high longitudinal fields on asymmetry***

4. Magnetic Fields

5. Beam size, event rate and steering

A set of collimation slits in the MuSR beamline just after the kicker can be used to control the size of the muon spot and the rate at which muons hit the sample. The muon beam can also be steered by small amounts in the horizontal and vertical directions to allow it to be centred on a sample.

5.1 The muon beam spot size

The muon beam spot is elliptical. Its size in the horizontal direction can be changed using a set of slits in the beampipe which are controlled from a panel located behind the EMU area under the mezzanine floor.

CARE SHOULD BE TAKEN TO CHANGE ONLY THE MuSR SLITS

As a guide, set the x-slit equal to the x dimension of the sample, then check the data collection rate.

The beam spot size in the vertical direction cannot be altered, and is of the order of 8 mm FWHM.

The beam spot size in the MuSR CCR has been measured for various settings of the beam slits using a haematite sample with a 20 mm diameter silver mask on top. Muons falling on the haematite are rapidly depolarised, whereas those falling on the silver maintain their polarisation. The amplitude of the muon precession signal in an applied transverse field (20 G) is a measure of the fraction of muons falling on the silver and therefore of the muon spot size. Full asymmetry (of 25.9%) was measured using a plain silver plate with no haematite. The results are shown in the plot below.

It should be noted that these measurements were performed in the MuSR CCR with its heat shield and tails in place. The window in the CCR tails (80μm-thick Mylar) introduces some scattering of the beam, increasing the beam spot size slightly: with the CCR tails removed, an asymmetry of 3.7% was obtained, equivalent to 16% of the muons falling on the mask. The spot size is larger still in

the orange cryostat, dilution fridge and furnace, which all have additional windows: typically 30% of the muons fall outside a 20 mm diameter area inside the orange cryostat with the slits set to 8.

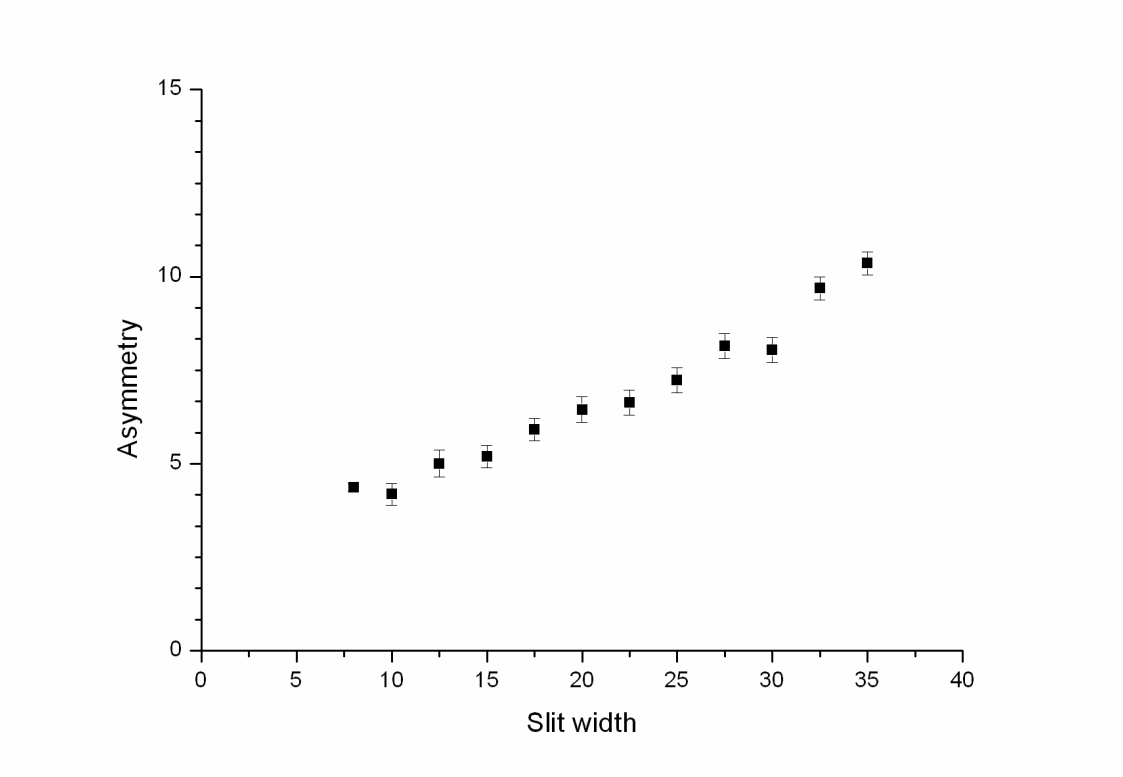


Figure 13. ***Measurement of the muon beam spot size***

The table below gives similar results, expressed as fraction of beam falling on to the mask, as a function of mask size for two slit settings, again in the MuSR CCR. The measurement errors are +/- 1%.

slit setting	10 mm mask	20 mm mask	25 mm mask	29 mm mask	38 mm mask
12	60.7%	20.1%	12.4%	8.2%	< 4%
20	63.7%	25.6%	15.6%	8.7%	< 4%

Please note that the above figures are guides only. The actual size of the muon spot at a particular time is dependent on factors such as the tuning of the extracted proton beam, and can vary slightly from cycle to cycle.

5.2 The event rate

In addition to controlling the muon spot size, the slits can be used to regulate the event rate and thereby control the distortion at the start of histograms due to detector dead time effects. Because various parts of the detector have limitations on the speed with which they can respond there is a dead time, t_d, after each event during which further positron decays are missed. The effect of this dead time can be modelled and the reduced rate observed in the experiment, r_{ob}, is found to be related to the true rate, r, by the expression $r_{ob} = r/(1+rt_d)$. Although the effect is particularly evident at high event rates, some distortion is always present. Users should therefore always consider using the facilities provided by both UDA and RUMDA to correct for this effect when analysing data. The effects of deadtime on data are shown in figure 16 of section 9.3.

Rate must be kept below 55MeV/hr as this will give DAE2 more hits per frame than it can cope with.

The graph below shows the event rate as a function of slit width for a large silver plate mounted on the MuSR CCR with the 10 mm muon production target in use and with ISIS running at about 170 μA. The main curve was taken without the CCR tails in place - addition of the tails reduces the event rate slightly (point shown as a cross) and also slightly increases the maximum asymmetry (this effect is greatest in the furnace, where the event rate is two thirds of that in the CCR and the asymmetry is typically a couple of percent higher).

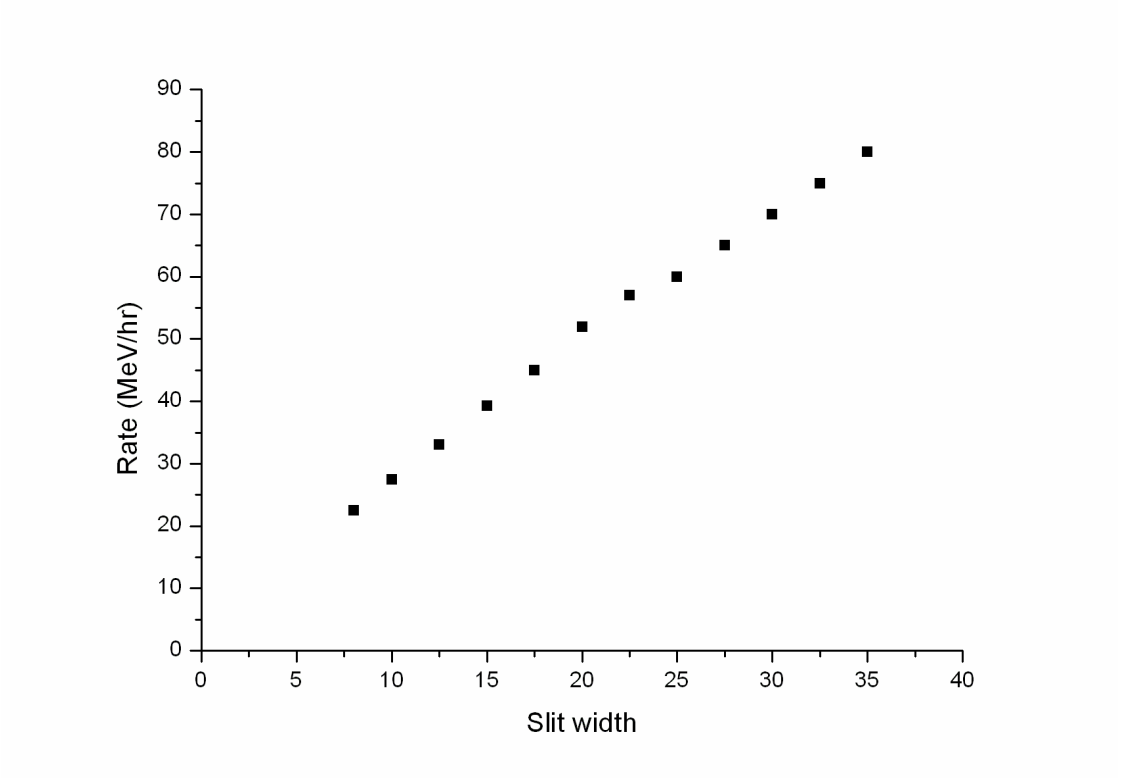


Figure 14*. Event rate as a function of slit setting*

It should be noted that the 'figure of merit' for an experiment is given by (asymmetry^2 x rate), so that small changes in asymmetry can be significant.

5.3 Steering the beam

The muon beam can be steered by small amounts to centre it on the sample under investigation. Particularly when small samples are being used, it is important to ensure that the beam is steered correctly to maximise the fraction of muons hitting the sample. Also, in transverse geometry, the applied transverse field shifts the muon beam spot slightly in the vertical direction and it is necessary to compensate for this. On MuSR it is possible to steer the beam in the horizontal and vertical directions using dipole magnets in the beamline. These are controlled from the two Kingshill power supplies at the bottom left of the rack in the back of the MuSR cabin; the current is set on the front of each supply. The horizontal steering is more sensitive than the vertical (the horizontal steering magnet being located further upstream) - movement sensitivity is approximately 25 mm/A horizontally and 5 mm/A vertically. Making the current for the vertical magnet more negative moves the beam downwards.

The two plots below are examples of steering curves produced in the MuSR CCR. The best settings for the steering magnets shown here should not be used in general as they depend on the precise sample position. However, the curves can be used as guides to the steering magnet sensitivity.

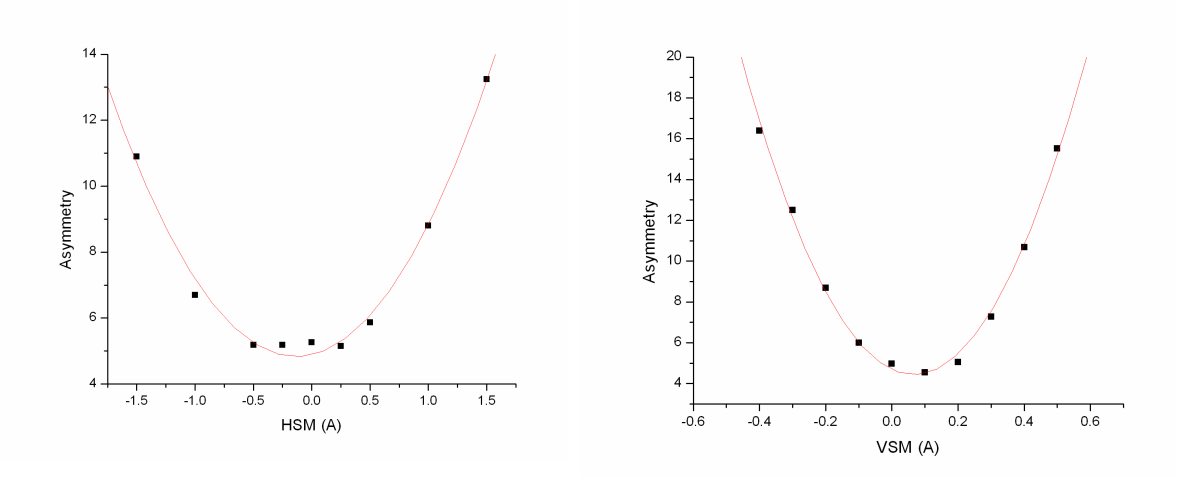


Figure 15. ***Steering curve examples***

The above curves were produced by observing the muon precession amplitude in a 20 G transverse field using a 20 mm diameter silver mask on a haematite sample with the beamline slits set to 8. The steering is therefore best at the asymmetry minimum.

6. Computing

This is a short guide to the computing facilities available to MuSR users.

6.1 General Information

- The two cluster computers available for MuSR users are **MUSR** and **ISISA.**

- **MUSR** is the **data acquisition computer** located in the instrument cabin. It can be used for analysis during an experiment, but cannot be logged in to remotely (due to ISIS-wide computer security measures).

- **ISISA** can be logged into from the cabin PC, from terminals in the DAC (Data Analysis Centre – the room by the users' coffee area), or remotely from your home institution, and can be used for data analysis, etc. It is the only ISIS node that can be logged into from off-site.

- The account MUSR01 is available to all users for data analysis.

- The PC in the MuSR cabin can be used for normal PC applications (Microsoft Office, Origin, SigmaPlot, Fortran) and as a terminal on to one of the cluster computers using the eXceed application.

6.2 Data acquisition

- Logging onto NDXMUSR

Using the right hand PC (the one with 2 screens) log in using the musr account. The password is on the whiteboard. Then select the remote terminal connection to NDXMUSR on the desktop. This should automatically log you in and SECI will either start or already be running.

6.3 Data analysis

6.3.1 Logging on

- **Logging in through an Xterminal.** These terminals are available for users in the Data Analysis Centre (DAC). Click on the 'CREATE' option at the top of the terminal manager window, and select 'DECterm' followed by the machine you wish to connect to. Then log in as normal using either the MUSR01 account or your own account.

- **Logging in through a PC.** The PC in the MuSR cabin (and other public access PCs) can be used as terminals to log on to **ISISA** using the eXeed application. On the MuSR PC, click on one of the terminal icons on the desktop. If you choose one of the MUSR01 icons, you will just be asked for the current password; otherwise, enter a username and password. A terminal window will appear after a few seconds. In order to allow graphics displays from UDA and other software to appear on the PC screen, it is necessary to type

  ```
  SET DISPLAY/CREATE/NODE=<node>/TRANSPORT=TCPIP,
  ```

  where <node> is the IP number of the PC you are using (the node name and IP number of the MuSR PC. This can be found by typing ipconfig in a DOS command prompt).

6.3.2. Using the MUSR01 account for data analysis

1. Log on to **ISISA** or **MUSR** with the username MUSR01. The password is changed periodically - contact an instrument scientist to obtain the current one.

2. Once access has been obtained, a list of users known to the account is displayed. Select the most appropriate, or alternatively use USERX, and type the name at the prompt. The cursor should change to reflect the current user. For example, USERX would proceed as follows:

```
Users                                                          known:
SCRATCH     RAL          RUNI         BIRMINGHAM SUSSEX     SHEFFIELD
STUTTGART   SOTON        PARMA        UPPSALA     OXFORD     LEICESTER
BS          LPOOL       CNRS        ILL         USERX      BRAUNSCHWEIG
STANDREWS       CSIC                      PARIS                   LYON
```

```
MUSR01>                                                          USERX

*********************************************************
          YOU    ARE    NOW    WORKING    ON    THE    SCRATCH    DISK
      FILES   IN   THIS   AREA   WILL   BE   DELETED   AFTER   7   DAYS
                  USE:        SETUP        to        access        UDA
*********************************************************

USERX>
```

3. Now type `SETUP`. A list of the analysis software currently available will be displayed. Any of these may be used by typing the program name. For example, to run UDA, USERX would proceed as follows:

```
USERX>                                                           SETUP

Commands                                                    available:
    TLOGGER        -        plot        temperature        logs
    HISTO     -     look     at     the     raw     histograms
    CONVERT_ASCII - turn the binary run data into ASCII format
    HEADERS - make a list of MuSR data file header information
    ASYM       -       analyse       levelcrossing       data
    UDA      -      standard      muon      data      analysis
    RESTMUSR    -    restore    datafile(s)    from    archive
    PRINT_MAN  -  print  the  MuSR  manual  on  LSR5  (MuSR  Cabin)
    SUPERPLOT       -       general       plotting       program
    SUPERPLOTC      -      for      plotting      in      colour

If    access    to    RUMDA    is    required    type    RUMDA

If access to MESA or TDSA is required type MESA_SETUP

USERX>                                                             UDA
```

4. If access to RUMDA and GENIE is required type `RUMDA`. Again, a list of the available commands will be displayed which give access to the RUMDA programs. TDSA, an alternative analysis program, and MESA, a maximum entropy analysis program for transverse field data, are available `MESA_SETUP`.

6.3.3 Using your own account for data analysis

1. Login to **ISISA** or **MUSR** with your own user name and password
2. Type `@musr$disk:[mumgr.musr_users]musr_setup` to gain access to the data analysis software.
3. You may want to edit your LOGIN.COM file (found in your top-level directory) to add the line (preferably at the end of the file):
   `$ setup :== "@musr$disk:[mumgr.musr_users]musr_setup"`
4. Typing `SETUP` when you next login will work as described above for the MUSR01 account.

NB. If you use both MuSR and EMU instruments, you may wish to add two lines to your LOGIN.COM file, one for `MUSR_SETUP` and one for `EMU_SETUP`, as the SETUP files for the two instruments are different. The `EMU_SETUP` command can be found in the EMU User Guide.

6.4 Utility programs

6.4.1 CONVERT_ASCII: converting data files to ASCII format

The binary files written by MCS can be converted into ASCII files in one of three formats: firstly, in the same format as read by UDA's 'USRFILE' option; secondly, as a column of raw counts for each histogram (this is ideal for loading into PC spreadsheet applications); thirdly, as asymmetry data (this format can be directly imported into PC analysis programs such as Origin). The conversion program is run from account MUSR01 using the command `CONVERT_ASCII`. The program prompts for first and last files to be converted and the format of the output ASCII data. Depending on the output ASCII file format required, additional information may be requested.

When using format options two or three it is very important that correct values are entered for both the t_0 and α. Check also that the grouping used in option three corresponds to the current detector arrangement.

6.4.2 TLOGGER: plotting TLOG files

A plot of the temperature log for a data run may be produced using the command `TLOGGER`. The program will request the beamline (select option '2' for MuSR), a run number and the type of graphics device you are using to view the plot (enter `/xw` when using DECwindows). The file number need not have preceding zeros. The TLOG file with highest version number is plotted for the given run; files with lower version numbers are displayed by typing the complete file ending: e.g. `00123.TLOG;1` will plot R00123.TLOG;1. The hard copy option produces a postscript file PGPLOT.PS, and this may then be sent to the MuSR laser printer using the command `PRINT/QUEUE=POST$LSR5 PGPLOT.PS.*`.

6.4.3 ISISNEWS: the status of ISIS

Typing `ISISNEWS CURRENT` at the DEC prompt gives news on the status of ISIS. Information may also be obtained from looking at the messages in Bulletin, type `BULLETIN` at the prompt.

6.4.4 Archiving data on to a PC floppy disk

Data may be archived on to an IBM PC format floppy disk as follows:

- Convert all data files to ASCII format using CONVERT_ASCII.
- On a PC launch the FTP application by double clicking the left mouse button on the 'WS_ftp32' icon on the left of the desktop.
- The program automatically comes up with a window requesting details of the connection to be made. The 'host name' should be set to `isisa.rl.ac.uk`. Enter a user name (eg. MUSR01) and password and click on OK.
- When the connection is made and WS_ftp32 has read in the remote directory, set the appropriate PC directory using the ChgDir box on the left hand side of the WS_ftp32 window (set this to a: for transfer to a floppy), and the mainframe directory on the right hand side (for the MUSR01 account, files will be in `scratch$disk:[musr01.users.userx]` where you should replace `userx` with your own area name.
- For ASCII data, ensure that the ASCII button, below the windows showing files, is checked.
- Highlight the files you wish to transfer and click the appropriate arrow between the two file windows to copy the files.
- Further information can be found in the on-line help within the program.

6.5 The MuSR PC

The PC in the MuSR cabin is available for use as a terminal or to use one of the software packages installed (the PC has Microsoft Office and Origin, as well as normal applications). If it becomes necessary to reboot the PC, the login name and password are on the board in the cabin. To start applications, either click on the appropriate icon on the bar on the right hand side of the screen, or use the 'START' menu from the bottom bar. Please ask your local contact for further information if you are unfamiliar with the Windows XP system.

6.6. Printers

The following printers are available for users:

Black and white laser printers:
LSR0 (R3 Computer Support Office),
LSR1 (R3 2nd floor),
LSR2 (R55, DAC)
LSR3 (MARI cabin)
LSR4 (CRISP cabin)
LSR5 (MuSR cabin)
LSR7 (PRISMA cabin)
LSR8 (SXD cabin)
LSR10 (outside EMU cabin)
LSR11 (HET cabin).

Colour printers:
R3_COL00 (R3 Computer Support Office)
R3_COL01 (R3 2nd Floor),
POST$INK0 - (Deskjet 1200 in MARI),
POST$INK2 (Deskjet 1200 in DAC),
POST$INK4 (Deskjet 1200 in CRISP).

To print PostScript files on the MuSR cabin printer:

```
print/que=post$lsr5 [file.ps]
```

and to print text files:

```
print/que=ansi$lsr5 [file.txt]
```

7. Data acquisition: SECI

The sample environment and data collection on MuSR are controlled by a computer program "SECI" running on the computer NDXMUSR.

Starting a Run

Type *begin*

Ending a Run and saving the data

Type *end*

Ending a run without saving

Type *abort*

Pausing a run

Type *pause*

Then to continue the run

Type *resume*

Setting a temperature

Type *settemp* <value>

Setting a field

Type *setmag* <value>

Selecting T20 power supply and setting 20Gauss

Type *TF20*

Selecting Danfysik power supply

Type *lf0*

Selecting auto-zerofield

Type f0

Automatic running of MuSR

Scripts are created on the mkscript3 panel and should be saved on the u: drive. To load a script

Type load "u:\<nameof script>.gcl"

To run a script

Type Runscript

To keep the current run going type keep in the custom column

To end a script

Type <crtl> C

Should mkscript3 crash then the easily way to restart mkscript3 is to restart SECI.

Under Start (bottom left) press killseci.cmd

Wait a minute or so

Then under Start press startstation.cmd

If this is not possible or desirable then the mkscript3.exe program can be found in directory "c:\labview modules\mkscript3". However, SECI will not have control of the window.

Setting the label

Type setlabel /qualifier

/s for sample
/c for comment
/u for user
/rb for rb number
/t for temperature
/f for field
/g for geometry
/o for orientation

You will be prompted for information

Changing configurations:

- Select Configurations from the ISIS SECI window
- Select Open Configuration
- Select Correct configuration (please do not save configurations)
- SECI should start the correct vi's which are currently not running and close any that are not needed
- Type getblocks in the Opengenie window

Blue Cryostat

For operation below 5K
Type blue_lt
For operation above 5K
Type blue_ht

The temperature parameter files:

For all configurations the tpar files are in "C:\labview modules\mkscript3" directory and are called "muon_temperature.tpar"

Displaying all control blocks

Type cshow/all

8. Data analysis: UDA

8.1 Introduction

UDA is the simplified μSR data analysis program. There are three menus in UDA, the Main Data menu, the UDA data Grouping menu and the UDA data Analysis menu.

On start-up the program will always enter the Main menu. At this menu you can read and write data files, plot spectra and make changes to the data loaded.

In the data Grouping menu you can select how to map your raw histograms into the "groups" that are used when plotting or analysing. Two different grouping schemes can be used, the Simple (straight, TF) grouping, or the F-B (LF,ZF) grouping. Deadtime correction of data is available using the same correction method as the RUMDA analysis program.

In the Analysis menu you can select a model function and make a least-squares fitting of the model parameters. The fitting result can also be plotted from this menu.

8.2 Running UDA

To access UDA from account MUSR01 type `SETUP followed by UDA as described in section 6.3.` This will run the most recent version of UDA. The display will be redrawn as a dashboard and the cursor will automatically select the option MCSFILE in the Main menu. To select any other item from the menu use the cursor (arrow) keys or simply type the first letter of that item (e.g. ‘P’ for PLOT).

8.3 The Main Data Menu

The Main Data menu allows you to read, write and modify experimental data. The options available from this menu are listed below. Plotting of error bars on data points can be turned off/on using the SETUP option.

MCSFILE	Read a MCS run file in the format used by the data acquisition software
USRFILE	Read a uSR file from the disk
NEXUS	Read a NeXus File (the new and only data format on MusR)
WRITE	Write (grouped) data to a uSR file
INSPECT	Inspect run and all histograms
GROUP	Enter the Grouping Menu
CHANGE	Change run file parameters
PLOT	Plot one or more groups on the terminal screen
ANALYSE	Enter the analysis menu
SETUP	Set program configuration parameters
HELP	Enter the VAX/VMS help facility to read the UDA help library.
QUIT	Exit UDA and return to VMS prompt

8.4 The Grouping Menu

The grouping menu is accessed through the option "Group" from the Main menu, and defines the grouping and correction of raw histogram data. There are currently two ways of grouping the histograms:
a) the Simple grouping, where histograms are simply added together.
b) the Forward-Backward (F-B) grouping, where the 'asymmetry ratio' $(F-\alpha B)/(F+\alpha B)$ is calculated.

Deadtime correction of data is turned on/off using the DeadT option. To compensate for deadtime, UDA uses the same file of deadtime values as the RUMDA analysis program, generated at the start of each cycle from a long silver run. Please ask your local contact if you are analysing data from a previous cycle and so require UDA to use deadtime values from that cycle rather than the current deadtime file. The effects of deadtime correction are shown in figure 16 of section 9.3.

The options available for grouping and correcting data are shown below.

CHANGE	Change histogram grouping
READ	Read grouping table from disk
WRITE	Write grouping table to disk
DEADT	Switch deadtime correction on/off
ALPHA	Select (F-B) scaling factor
GUESS	Estimate alpha for a T20 run
BUNCH	Setting the bunching to ‘n’ adds ‘n’ bins together.
HELP	Display help text. (Don't panic)
EXIT	Return to UDA Data (main) menu

8.5. The Analysis Menu

The Analysis menu is entered by selecting the option ”Analyse” in the UDA Main menu. Using the options outlined below it is possible to select a model function

and make a least squares fit of the model parameters. The results of the fit can also be plotted and output to an ASCII file.

SELECT	Select a group and a bin range to work on.
PLOT	Plot the data and the fit; allows fit to be written to an ASCII file
FIT	Run fitting routine using the starting values displayed in right hand window
HELP	Enter the help system at the Analysis menu level
VALUES	Enter the parameter display to change parameter values/status. To move in the parameter display use UP or DOWN cursor keys. To change a value use the ENTER key. Status codes are changed by typing ~ (vary parameter), ! (fix parameter), = (tie parameters together). Return to the menu by the left or right cursor keys.
THEORY	Select a theory function, number of sub-components and lineshape
ALPHA	Change value of alpha
UNDO	Undo fit and restore original parameters
EXIT	Exit this menu and return to the main UDA menu
WRITE	Write parameters out to a file
READ	Read parameters in from a file
DIST	Distribute parameters to all groups (necessary for transverse geometry)

8.6 Computer files

These files must be copied into the area you are working in. If the area has been selected by `SETUP (as described in section 6.3)` they will have been copied to the new area automatically.

SETUP.UDA	UDA reads some variables from the file SETUP.UDA. In particular the directory address of the data is set up in this way. Of particular interest are the FORTRAN format strings used to convert a run number to a full file name.
BASETIME.UDA	contains the value which UDA will use for time-zero (see section 8.8).
TRANS.UDA	default transversal grouping
LONG.UDA	default longitudinal grouping
PDF.UDA	parameter definition file
UDAHELP.HLP	help library source, UDA matters

8.7 Theory functions defined in UDA

A number of theory functions are predefined in UDA:

8.7.1 Longitudinal and zero field

Function Name	Definition
1. Lorentzian	$a_o \exp(-lt)$
2. Gaussian	$a_o \exp(-(lt)^2)$
3. LX(exp) - Stretched Exponential	$a_o \exp(-(lt)^b)$
4. Keren LF (extended Abragam)	$a_0 \exp(-G(t)t)$; see note 1 below
5. Kubo-Toyabe (Gaussian)	$a_o(⅓ + ⅔(1-(lt)^2)\exp(-(lt)^2/2))$
6. Kubo-Toyabe (Lorentzian)	$a_o(⅓ + ⅔(1-lt)\exp(-lt))$

8. Dynamic Kubo-Toyabe	see note 2 below

Note 1:

$$G(t)t = \frac{2D^2}{(w_s^2 + n^2)^2}\{[w_s^2 + n^2]nt + [w_s^2 - n^2] \times [1 - \exp(-nt)\cos(w_s t)] - 2nw_s \exp(-nt)\sin(w_s t)\}$$

where UDA's sigma is equivalent to D, UDA's tau is equivalent to $1/n$ and $\omega_s = \gamma_\mu B_0$.

Note 2: Function 8, the dynamic Kubo-Toyabe, uses numerical integration to produce the fitting function and so requires more time than the other functions. Only fit up to channel 1000 when using this option.

8.7.2 Transverse field

Function Name	Definition
11. Lorentzian with freq	$a_o \cos(wt + f)\ \exp(-lt)$
12. Gaussian with freq	$a_o \cos(wt + f)\ \exp(-(lt)^2)$
13. LX(exp) - Stretched Exponential with freq	$a_o \cos(wt + f)\ \exp(-(lt)^b)$
14. Abragam with freq	$a_o \cos(wt + f)\ \exp(-(lt_c)^2\ (\exp(-t/t_c) - 1 + t/t_c))$

8.8 Time-zero

Time-zero is usually taken to be the arrival time of the centre of the muon pulse. On MuSR, which receives the second of the two muon pulses produced by the proton beam, this is found to be 0.645 μs after the timing start signal produced by the Cerenkov counter near the muon production target. This corresponds to slightly after the start of bin 40 in the detector histograms (for a bin size of 16 ns). UDA uses this value to set its time-zero position (it is written in the file *basetime.uda*). However, useful data is not produced until after the complete arrival of the muon pulse, so that bins 46 and above can be used for function fitting, etc.

9. Other components of the muon beamlines

9.1 Beamline power supplies

Located at intervals along the muon beamline between the production target and the spectrometer are dipole and quadrupole magnets which respectively act to steer and focus the muon beam (see figure 1 at the foot of the Contents pages). Most of the beamline magnets are located before the kicker, and therefore any faults will affect all three muon beamlines; however there are also two quadrupoles specifically for MuSR located after the kicker. The power supplies for all the beamline magnets are located on the raised platform on the far East side of the experimental hall (the steps up to this are opposite the steps taking you over the proton beam to the other side of the hall).

On the left at the top of the steps on the platform, and working towards the far wall, are the following units:

1	3	6	9				15	17	20	23
	4	7	10	12	13	14		18	21	24
2	5	8	11				16	19		25
									22	26

Figure 16. ***Beamline power supply layout***

1 Reset buttons for beamline magnet klixons, flow and earth leakage trips
2 Q1 supply
3 Separator B-field supply
4 Q2 supply
5 Q3/5 supply
6 Q4 supply
7 Q6 supply
8 Q7 supply
9 Q8 supply

10 Q9 supply
11 B1/2 supply
12 DEVA Helmholtz supply
13 DEVA septum supply
14 EMU septum supply
15 Reset buttons for quads/coils on individual beamlines
16 Panels showing on/off status of klixons, etc, for quad/coil supplies
17 Q10A supply (DEVA)
18 Q11A supply (DEVA)
19 Q12A supply (DEVA)
20 Q10B supply (MuSR)
21 Q11B supply (MuSR)
22 switchyard magnet supply
23 Q10C supply (EMU)
24 Q11C supply (EMU)
25 Q12C supply (EMU)
26 switchyard magnet supply

The normal working currents for these supplies are shown by them, but call your local contact if you think there is a fault.

9.2 The separator

The separator is located in the muon beamline before the kicker and acts to remove contaminant particles (primarily positrons) from the muon beam. It consists of mutually perpendicular E and B fields which act as a velocity selector. The settings of the two fields are correlated so that muons of a particular velocity are transmitted: with the E field at 100 kV, the B field supply must be run at 43 A (and with E at 90 kV, the B field requires 39 A, etc). The power supply for the B field is located with the other beamline power supplies (see section 9.1); the E field is controlled from a unit located below the mezzanine floor behind the EMU area. The required voltage for the separator E field can only be achieved by 'conditioning'; that is slowly increasing the voltage until the field breaks down and leaving it at this setting for a period before increasing it further. This process is done at the start of each cycle, but is often required during the middle of a cycle if the separator voltage becomes unstable.

9.2.1 Spin rotation by the separator

When the muon beam is deflected by a magnetic field the spin and momentum vectors remain collinear. However, the same is not true if the beam is passed through an electric field, when the muon spin is rotated with respect to its momentum vector. The effect of the electric field in the separator is to rotate the muon polarisation upwards slightly by about 6^{o} so that there is a component transverse to the momentum direction. This rotation is best observed by examining individual detectors for data taken in small longitudinal fields (up to ~400 G). Under these circumstances there is a precession of the muon spin in the field and an oscillating signal can usually be seen. Shown below is the signal from detector 1 for a silver sample in an applied longitudinal field of 50 G. The oscillations shown have an asymmetry of 2.2%.

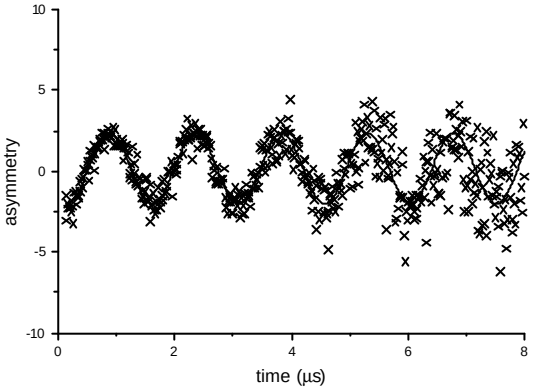


Figure 17. ***Spin rotation by the separator seen in a single detector***

By grouping the detectors, however, the effect is removed. The graph below shows the data from this run arranged into a forward-backward grouping. This plot also shows the effects of deadtime: the grouped data is displayed with (crosses) and without (line) deadtime corrections.

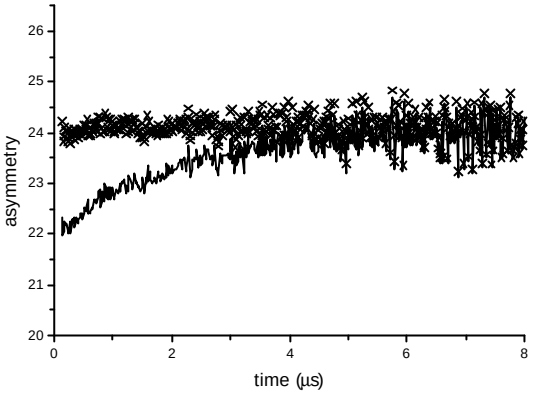


Figure 18. ***Grouped data with and without dead time correction***

9.3 The kicker

The kicker is responsible for supplying muons to the DEVA and EMU areas. Muons are generated at the production target with the same time structure as the main proton beam, i.e. two 80 ns wide pulses separated by 300 ns (50 times per second). The first of these pulses is split in two in the kicker by a central electrode at high voltage. This kicks half the pulse to the left and half to the right, feeding the two side beamlines. In the time between the two muon pulses the voltage on the electrode is reduced to zero, and the second pulse travels undeflected to MuSR. The kicker power supply is located under the mezzanine floor behind the EMU area and consists of a high voltage supply together with timing electronics to ensure that the kick occurs at the correct point with respect to the muon pulses. The timing signal is taken from a lead glass Cerenkov counter located near the muon production target and fed to a delay unit. Instructions on how to reset the kicker are given in section 10.5, but this should only be done by an instrument scientist.

9.4 The photomultiplier tubes

The photomultiplier tubes on the spectrometer are powered from one of the LeCroy crates in the back of the EMU cabin. (The crates are labelled MuSR and EMU - make sure you switch the correct one on or off if you have to). Slots 2 and 3 of the MuSR crate are used to power the MuSR PMTs, with 16 outputs from

each slot (addressed 0-15, *not* 1-16). Once the LeCroy crate is powered up it can be controlled from the terminal in the back of the MuSR cabin. It should only be necessary to modify the PMT voltages in two circumstances:

- when rotating the instrument all tubes should be turned **OFF (don't forget to turn them back on again afterwards!)**
- if a scintillator develops a light leak, please turn off the volts to its PMT.

The most commonly used commands for controlling the PMTs from the terminal are shown in the table below.

Command	**Action**
ON,OFF	switch the voltage on all tubes on or off
RE(2-3,0-15)	displays the voltage on all MuSR PMT tubes
RE(slot, channel)	displays the voltage on one tube
WR(slot, channel)0	sets the voltage on a single tube to zero
WR(slot, channel)v	sets the voltage on a single tube to v
Ctrl C	stops screen scrolling

10. Troubleshooting

10.1 No muons

- Check the machine is running at a reasonable rate. In the MuSR cabin there is a proton per pulse (PPP) monitor displaying the pulse intensity in μA. If this reads 00 there are no protons, and if it is flashing any number then ISIS is not running at 50 Hz and therefore the count rate will be lower than usual.

- If ISIS is not running, check the facility status by typing `ISISNEWS current` in a decterm (not mcs control window) or http://www.isis.rl.ac.uk/status/index.htm

- Check the beam blocker is open: the gate must be closed and locked to allow this. The blue interlock light will be lit if this has been done correctly.

- Check that the high voltage to the photomultiplier tubes is on (this is particularly likely to be the problem immediately after the instrument has been rotated). The red lights on the photomultiplier tube bases should be on. If not, type `ON` on the terminal controlling the high voltage power supply in the back of the MuSR cabin (see section 9.4 for further details of the photomultiplier tube high voltage commands).

- Check the 'BEAM OFF' button on the fence in the zone is not pressed. If it is, release it, then restart the bending magnet power supply, B1/2, above the cryostat store using only the 'START' button (see section 9.1).

- Check that all the magnets are working by checking their power supplies (see section 9.1 - the current they should be set at is written on each). If necessary, reset or restart using the value given.

- Check that the kicker is working. Instructions for resetting it if it has tripped are at the end of this chapter, but please consult your local contact before doing this.

- Check that the separator is at its correct voltage - typically 90 kV.

10.2 Computer Problems: Restarting SECI

Goto the Start Menu and select killSECI. After SECI has stopped goto the start menu again and select startstation. If this does not resolve the problem then rebooting NDXMUSR might be necessary this can be done by type “ctrl –alt – end” together and then select shutdown. Please select restart or NDXMUSR will not restart!

10.3 Resetting the kicker

If the spectra from the individual detectors displayed on the MuSR data acquisition screen shows the effects of a double pulse the electrostatic kicker has failed and all the muons are passing undeflected through to MuSR. Before resetting the kicker check with the EMU and DEVA users that they have lost all beam. In most cases EMU and DEVA users will notice a kicker failure before MuSR users. The instructions for resetting the kicker are given below and are also attached to the kicker power supply unit.

- Turn key switch **A** through 90° to OFF position
- Turn helipot **B** fully anticlockwise to 0.0 volts
- Wait a few seconds
- Turn key switch **A** through 90° back to ON position
- Observe LED display on front panel. Only the +120I(A) and +120I(B) and the (large) "DELAYED POWER ON" should be unlit at this stage
- After 120s the +120I(A) and +120I(B) LEDs will light
- After a further 180s the "DELAYED POWER ON" will light and the high voltage power supply will be powered up

- Dedicated trigger should light

- While pressing the "READ SET VOLTS" push button turn helipot **B** slowly clockwise to obtain a set volts readout of 32.5kV. The current read-out will be ~2.02mA when the push button is released

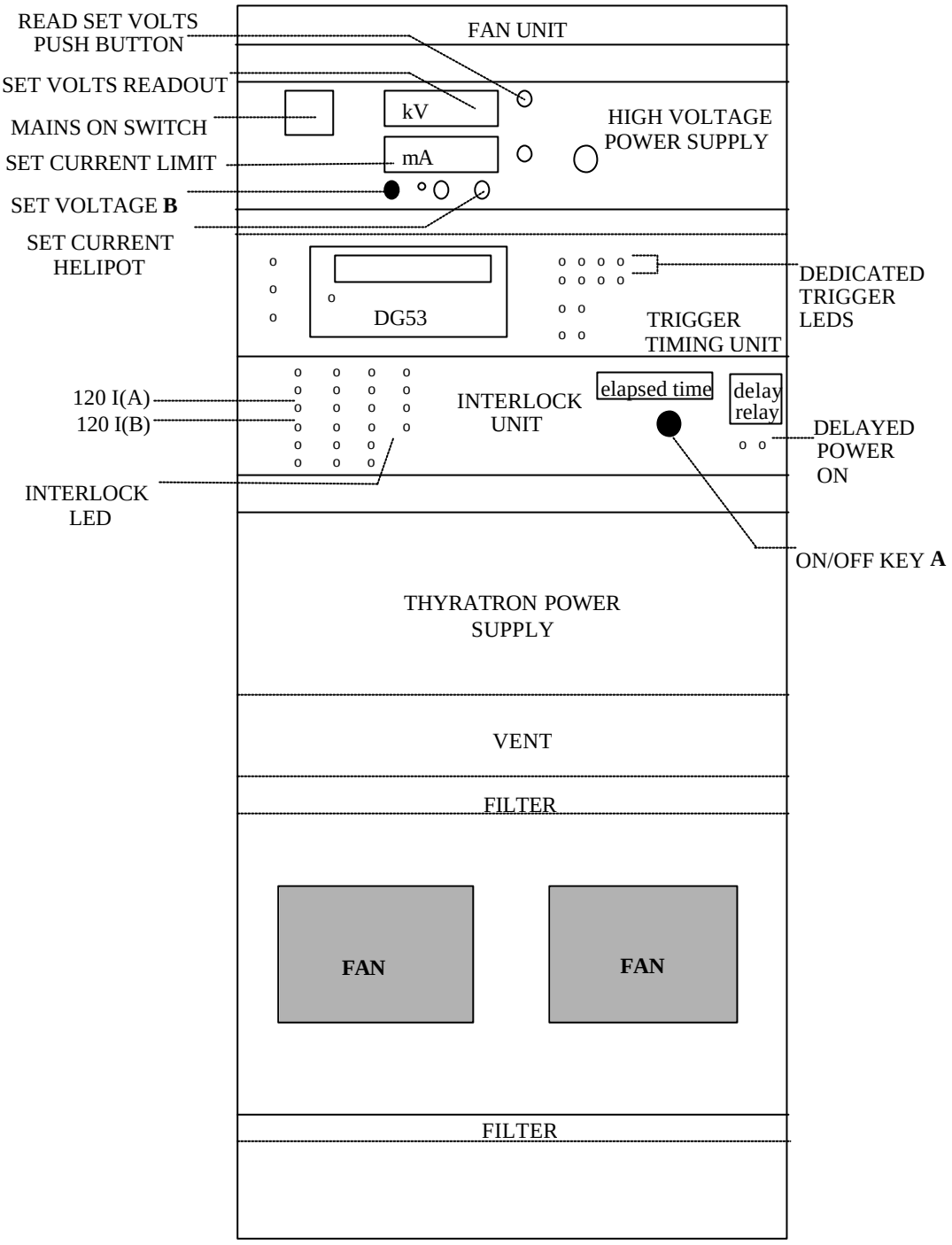


Figure 19. ***Reference diagram for resetting the kicker***

11. Contact Points and further information

11.1 Laboratory contact points

Rutherford Appleton Laboratory,
Chilton,
Didcot,
Oxfordshire,
OX11 0QX. ☎ (01235) 821900 (national)
☎ +44 1235 821900 (international)

Main control room (MCR).....☎6789
EMU cabin (R55) .....☎6831
MuSR cabin (R55) .....☎6135
DEVA cabin (R55).....☎6851
Experimental Areas .....☎6338
ARGUS/RIKEN……☎6766
Health Physics/ Sample checking ..☎6696
Computer support.....☎1763 (7770858090 from outside the lab)
University Liaison Office.....☎5592
Cosener's House .....☎3007 or (01235) 523198
Local taxi's.....☎5592 (during the night ring the MCR)
Airport transportation (24hrs notice required) ☎5592
Gas bottles (He, N_2 etc).....☎6166

11.2 Contacting an instrument scientist

Stephen Cottrell	☎5352 or 1665	(Email: s.p.cottrell@rl.ac.uk)
Adrian Hillier	☎6001 or 1476	(Email: a.d.hillier@rl.ac.uk)
Philip King	☎6117 or 1716	(Email: p.j.c.king@rl.ac.uk)
James Lord	☎5674 or 1101	(Email: j.s.lord@rl.ac.uk)
Francis Pratt	☎5135	(Email: f.l.pratt@rl.ac.uk)

From **outside the laboratory** certain extensions may be direct dialled, the number being formed in the following manner:
(01235) 44xxxx, where 'xxxx' is the required extension.

No prefix is needed to dial offsite.

11.3 Further information on the ISIS muon beamlines

For further information on the ISIS muon beamlines, see

Commissioning of the Rutherford Appleton Laboratory pulsed muon facility *GH Eaton et al.* Nucl. Inst. Meth. A269, 483-491, 1988.

The ISIS pulsed muon facility: past, present and future *A Carne et al.* Hyperfine Interactions 65, 1175-1182, 1990.

UPPSET: a pulsed electrostatic kicker to improve the μSR frequency response in the ISIS pulsed muon beam *AI Borden et al.* Nucl. Inst. Meth. A292, 21-29, 1990.

The ISIS pulsed muon facility *GH Eaton* Z. Phys. C 56, S232-239, 1992.

The muon beamline at ISIS *GH Eaton et al.* RAL Report RAL-94-077.

The development of the pulsed muon facility at ISIS *GH Eaton et al.* Hyperfine Interactions 87, 1099-1104, 1994.

Fast E-field switching of a pulsed surface muon beam: the commissioning of the European muon facility at ISIS *GH Eaton et al.* Nucl. Inst. Meth A342, 319-331, 1994.

The ISIS muon group Web pages also contain additional information on the muon facility, as well as the current instrument schedules, etc.; the address is
http://www.isis.rl.ac.uk/muons

The main ISIS web pages contain details of all ISIS facility activities, together with information on applying for beamtime, electronic versions of proposal forms and A3 report forms, latest beam information, etc. They can be found at http://www.isis.rl.ac.uk.

11.4 Local information

11. Contact Points

Transport

National Rail Enquiries It is usually possible to arrange a taxi to either Didcot Parkway or Oxford stations.	0345 48 49 50 or http://www.railtrack.co.uk/travel/
The Oxford Bus Company Oxford city local buses and coaches to London (X90), Heathrow (X70) and Gatwick (X80).	01865 785400 http://www.oxfordbus.co.uk/index.html
Stagecoach Bus Company (formerly Thames Transit) Oxford city and rural bus services including routes to/from Harwell bus station near main gate.	01865 727000
BAA Flight Information Arrival information for many UK airports including Heathrow and Gatwick.	http://www.heathrow.co.uk/baainfo/baainfht.html

General Information

Oxford Tourist Information Centre	01865 726871
Oxford Guide on the Web	http://www.comlab.ox.ac.uk/archive/ox/

Eating and Drinking

Didcot Tandoori, 222 Broadway, Didcot	01235 812206
Chhokar Tandoori, 226a Broadway, Didcot	01235 813573
Cherry Tree Inn, Steventon	01235 831222
Fleur de Lis, East Hagbourne	01235 813247
The George and Dragon, Sutton Courtenay	01235 848252
The Great Western Junction Hotel, Didcot	01235 511091
The Hare Inn, West Hendred	01235 833249
The Harrow, West Ilsley	01635 281260
The Plough, Sutton Courtenay	01235 848801
Red Lion, Drayton	01235 531381
Rose and Crown, Chilton	01235 834249
The Swan Inn, Sutton Courtenay	01235 847446
The Wheatsheaf Inn, East Hendred	01235 833229